SOME ASPECTS OF SIZE AND DISTANCE PERCEPTION WITH AN ULTRASONIC AID FOR THE BLIND

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INTRODUCTION

The invention of any new instrument as an aid to perception for the blind can give rise to at least two main types of psychological research.

I. That which is concerned with the evaluation of the man-machine system of user and instrument. Within this type of research there are five major sub-types.

a) That which looks at the system operating in the situation in which it will normally be used, (i.e. Field testing).

b) That which studies the system operating in a standardized and partially simplified situation which contains only those aspects of the field situation considered to be of crucial importance. (usually an obstacle course of some sort).

c) That which attempts to quantify the characteristics of the system by examining it in the restricted and controlled setting of the psychophysical experiment.

d) That which investigates background factors which predict skill with the aid.

e) That concerned with establishing the most efficient training programme.

2. That which is interested in the instrument, not for itself but for the light results may throw on perceptual processes in man, especially the area of perceptual learning.

Previous research with the Kay Ultra Aid for the Blind and for that matter, previous research on all other aids for the blind, has been limited almost entirely to Ia and Ib above.

This thesis is an attempt to examine some of the areas of research which, in the case of the Kay Ultra Aid, have been neglected to date.

The intention was to examine:-

I. The quantification of some aspects of size and distance perception using the aid. Measures were taken of (a) discrimination thresholds within these dimensions with other dimensions being held constant for the discriminanda.

(b) Judgements of equality on one dimension when the other dimension (and/or texture) is also varying, i.e. constancy.

2. The influence of a period of training and of the differential effects of movement during this training.

3. The relationship between auditory acuity, auditory discrimination, personality measures, and performance with the aid.

As far as the review of the literature is concerned it is clearly impossible to review all the literature in the area of perception. It was considered that constancy and the role of movement in perceptual learning should be emphasized in this thesis because of their relevance in the field of blind aids. Therefore, apart from studies relating directly to obstacle detection in the blind and aids for the blind, these are the only two areas given extended review

CHAPTER I

LITERATURE REVIEW

Obstacle Detection by the Blind

Any work with mobility aids for the blind must examine research into the obstacle detection of those who are deprived of vision, but have no artificial aid. The ability of the blind to detect obstacles has long been noted, the literature dates from 1749 when Diderot commented on the 'amazing ability' of the blind not only to perceive the presence of obstacles, but also to determine their position and nature. Diderot believed that this skill was due to the increased sensitivity of facial nerves to the pressure of air on the face. Since that time many more reports of obstacle detection and discrimination by the blind have been written and numerous theories about the basis of this phenomenon have been propounded. Hayes (1935) listed fourteen such theories in the following categories:-

1. Those that rest on sensory bases.
2. Those that rest on perceptual bases.
3. Those that rest on occult bases.

The sensory theories explain the phenomenon by hypothesizing heightened response of the receptor mechanisms of the non visual senses; the perceptual theories by claiming that it is based on the interpretation of the normal sensations from the activity of air or sound waves on the aural or skin receptors; and the occult theories in terms of magnetism, electricity or action of the vestigial organs of the skin and of the unconscious.

It was not until the 1890's that an attempt was made to subject any of these theories to an empirical test and so determine the objective basis of the phenomenon. Supa, Cotzin and Dallenbach (1944) summarized the literature before 1944 and concluded that:

"Not only are the blind who possess the 'sense of obstacles' unable to explain the basis of their performance, but, as this review shows, the investigators of the phenomenon are themselves unable to come to any agreement regarding it. Fact is entangled with theory and theory has, all too often, prejudiced interpretation of the experimental results." (Supa, Cotzin and Dallenbach 1944 p.138)

Since 1944 experimentation into the basis of the obstacle sense at Cornell University (Supa, Cotzin and Dallenbach, 1944; Worchel and Dallenbach, 1947; Worchel, Mauney and Andrew, 1950; Worchel and Berry, 1952; Ammons, Worchel and Dallenbach, 1953) and at the Institute for Experimental Psychology in Innsbruk (Kohler, 1952; Erisman and Kohler, 1953; Winkler, 1953) has shown that normal audition is the major basis for the detection of obstacles by permanently or temporarily blinded people. Smell, temperature and similar cues can be used, but play a small part unless audition cannot be used. Although the sound changes involved have not been fully specified, research by Truschel (1906); Cotzin and Dallenbach (1950); Thurlow and Small (1955); Thurlow (1957); Kohler (1964) and Bassett and Eastmond (1964) indicates that as the individual approaches a flat surface the sounds caused or emitted by him are reflected back to him with an increase in pitch; that this change is clearer with complex tones than with pure tones; with high tones than low tones and when the reflecting surface is at right angles to the subject. It is claimed that neither the loudness of the sound nor its continuity or lack of continuity is important.

The hypothesis that obstacle detection in the blind is based on auditory cues received additional support from the discovery that various animals utilize such cues, and with much greater precision than has ever been displayed by a human, e.g. a blinded bat can locate, identify as edible and then catch a moth, while both are on the wing (Webster, 1963), Porpoises (Kellogg, 1961), Rats (Rosenzweig, Riley and Krech, 1955) and other animals (Griffin, 1958) have also been shown to utilize auditory cues with amazing ability. Most of these animals emit ultrasonic pulses and utilize the echos. This fact probably accounts for their superiority over humans in this field as the ultrasonic echos contain much more information, particulary concerning very small objects.

To summarize, whether the blind do or do not detect obstacles by the use of auditory cues, ceased to be an issue after the definitive studies at Cornell (op.cit.). However, the details of what information is used and in what way it is used remain a subject for investigation.

In the 1950's research into obstacle detection by the blind changed from qualitative to quantitative analysis; that is, from an interest in discovering the nature of the major cues used to an attempt to measure the ability. Jerome and Proshanski (1950) obtained measures of the ability of four blind subjects to detect obstacles by asking them to walk out to a raised mark on the floor and state whether there was an obstacle in front of them. Twelve estimates were obtained from each subject (six with the obstacle present and six with the obstacle absent) at one foot intervals between three feet to nine feet from a mark on the floor. Ninety-four percent of the responses were correct when the obstacle was three feet from the mark and forty-two percent when it was nine feet from the mark. The subjects displayed a high level of accuracy up to seven feet when seventy-two percent of the responses were correct with a rapid drop to fifty percent correct at eight feet.

Kohler (1964) attempted to control for the sounds caused by walking, the nature of the floor and cues from the movement of the object, which he claimed were sources of error in the study by Jerome and Proshanski. Kohler used 297 blindfolded sighted subjects. Each subject was seated on a chair and presented with a cardboard disc fifty centimetres in diameter on the end of a bamboo pole. The absolute threshold of detection was determined by the method of average error. When no additional noise was provided, most subjects did not detect the obstacle until it was less than five centimetres from the subject. When additional noise was provided by a sonic guidance device, most subjects could detect an obstacle at one hundred and twenty-five centimetres. The difference between the unaided perforance of Jerome and Proshanski's subjects and Kohler's subjects could be due to the use of a smaller object; lack of noise from the subject such as walking noises; and/or lack of experience in auditory obstacle detection in the sighted subjects of Kohler's experiment.

Rice, Feinstein and Schusterman (1965) showed that it is the auditory angle subtended by the object and not its absolute size or distance which determines the absolute detection threshold of auditory perception. Thresholds obtained from five subjects for various size targets at distances ranging from 24 to 108 inches subtended a mean angle of 4.63° with a standard deviation of 0.21°.

Discrimination of size and distance by sightless human subjects have been examined by Kellogg (1962) and Rice and Feinstein (1965). Kellogg showed that the psychophysical discrimination function could be aplied to size and distance perception with audition, and that the obtained threshold for distance, expressed as a Weber fraction, (1/4) is slightly better than similar measure of monocular vision (1/2) presented by Howard (1919) but not as good as the measure of binocular vision (1/40) in the same study. As Kellogg measured discrimination at only one distance, the obtained Weber fraction must be interpreted cautiously.

Rice and Feinstein showed that when echodetection is used to discriminate objects of different sizes placed in front of the subjects, differences in area ratio as low as 1.07/1 could be discriminated, a level of discrimination similar to that shown by monkeys (Kluver, 1965) and Sea-lions (Schusterman, Kellogg and Rice, 1965).

Mobility Aids for the Blind

Although the blind person has limited perception of the environment beyond arms reach through auditory cues this is not sufficient to provide skilful and confident movement within this environment in all circumstances. Artificial aids have been constructed which attempt to enhance this auditory perception. Any such aid for the blind has two separate functions: to obtain information from the environment and to display this information to the human operator. Many mobility aids for the blind were developed from 1944-1951 but none passed the testing stage. Narrow beams of sonic and ultrasonic waves (mainly using pulsed signals), lightbeams and short electromagnetic waves were used to generate information about the environment which was conveyed to the operator by tactual and sonic techniques. Such information was usually limited to on/off information about the presence or absence of the object.

The devices developed during this period are reviewed by Beurle (1951) and Busher (1961). Conclusions drawn from tests on such devices can be summarized as follows:

1) Optical systems seem to show greater promise than those using either audible or inaudible sound waves.
2) A very simple form of presentation is essential.
3) Blind persons are averse to having artificial sounds fed into their ears.
4) They do not adapt easily to artificial aids.
5) An aid must be capable of detecting all forms of obstacle, including kerbs, with 100% certainty.

These conclusions lead to an almost complete cessation of work in England between 1950 and 1960 and to a concentration on optical systems to obtain information and on tactual display in the United States of America, leading to the development of the Obstacle Detector (OD) by the U.S. Veterans Association. However, the conclusions were based on failures in attempts to construct usuable aids and many variables must have contaminated the results. Kay (1964) suggests that one such contaminating variable was the limitations of the ultrasonic equipment available at the time. This equipment was bulky and capable of little frequency modulation. Kay (1962) and Pye (1960) claim that echolocation in the bat is based on frequency modulation and as the modern ultrasonic equipment is smaller and capable of considerable frequency modulation Kay has constructed an aid using a frequency modulated ultrasonic beam to obtain information about the environment. As this aid is manufactured by Ultra Electronics Limited it is known as the Kay Ultra Aid.

The Kay Ultra Aid emits an ultrasonic beam with a 'useful center' of ten degrees produced continuously with a sweep from 60kc per second to 30kc per second, the repetition rate being determined by a range switch. The waves reflected back to the receiver of the aid from any object in the path of the beam differ in frequency from those leaving it at that instant, by an amount proportional to the distance of that object from the Aid. This information, transposed to auditory threshold with a maximum pitch of 3kc, is fed to the operator through an earphone placed over the ear which does not prevent the sounds normally used in orientation from reaching the ear. The distance of the object reflecting the waves from the Aid determines the pitch of the signal; the further the object the higher the pitch. If objects at different distances reflect the beam at the same time the note received by the operator will contain all relevant frequencies. The size and the texture of the object determine the loudness of the signal, and the texture of the object also determines the timbre of the signal. The direction of the object can be determined only by scanning the environment. More detailed electronic specifications of the device are described by Kay (1963).

The information presented by the aid is very complex, but despite earlier claims that a simple form of presentation is essential, because no other aids have been developed with as complex a display, and as no research has been done on the advantages of different types of display, no *a priori* conclusion can be reached as to the advantage or disadvantage of the complexity of the display. Kay believes the extra information is useful and although the Kay Ultra Aid is an operating aid in itself it is seen by the designer as being of interest mainly as a developmental stage in the production of a stereophonic system which will give even more complex information including directional cues.

There has been an attempt by blind people and those working with them to specify the requirements of a mobility aid. These are merely suggestions with little research to support them and with little agreement concerning them, but, they should be considered as they will almost certainly influence acceptability of the aid. Starting from the basic assumption that, in order to be acceptable, a guidance device should provide a means for independent travel for the blind which is definitely superior to the existing means, Dupress (1962), Witcher (1964) and Leonard (1963) suggest that any such device should produce more useful information about the environment than can be obtained from existing sources, particularly that leading to the perception of steps and obstacles appearing at unexpected places and heights. But it should not provide so much information that the user is unable to utilize it when travelling at 4 - 5 miles per hour. Its use should not make its possessor conspicuous, or demand much maintenance and it should not require unduly great physical or mental effort, great ability, or too long a training period. Leonard (1963) and Goldstein (1963) suggest that we need to know the characteristics of the blind population and ensure that the aid demands only those skills that all, or nearly all, blind people possess.

Elliott (1966) claims, in opposition to the above, that the most important criteria for initial success of an aid are whether it enables the blind to detect obstacles, to navigate or to orient himself; comparison with other aids is only secondary. Gissoni (1966) claims that the most important requirement is that a sufficient proportion of the blind population have the necessary skills, find the aid acceptable and useful to make production and development worthwhile.

Evaluations of the Kay Ultra Aid for the Blind

The evaluation of any blind aid has two distinct aspects: first the evaluation of the device as a mechanical instrument, i.e., to ensure that the device presents reliable and valid information to the operator; and secondly an evaluation of the man machine system, i.e., given a satisfactory mechanical system we must examine what a man can do with the available information.

Delanie and Rennie (1965) have made a mechanical evaluation of the Kay Ultra Aid, provided a full description of the physical output of the Aid under different situations and set out specifications relating to operational performance. Such a physical evaluation of the Aid is essential but, as Riley, Weil and Cohen (1966) and Elliott (1966), point out, it cannot fully describe the nature of stimulation at the ear because of distortion between the earphone and ear, and falls far short of a satisfactory description of the nature of the information processed by the subject. Thus any evaluation of the device as an aid has to examine the man machine system of Aid and operator.

Evaluatory studies of the Kay Ultra Aid used by blind subjects have been conducted in the following areas:

1. Field Testing: Blind subjects are given some training in the use of the Aid and are left to use it in their everyday life. After a short period subjective descriptions of the nature and utility of the information from the Aid are obtained from these subjects. Leonard and Carpenter (1964) trained 11, mostly elderly, men from St. Dunstan's with ages ranging from 37 to 73 years, who had become blind late in life and were used to using a cane. After a three week training period those subjects

still interested (4 out of 11) were left to work alone with the Aid for a further five weeks. At the end of this period two subjects were still using the Aid, only one with any skill. Most subjects expressed favourable opinions of the Aid even though they did not find it personally acceptable.

Cranmer (1966) trained 17 adult subjects to use the Kay Ultra Aid offering continued ownership of it, for those achieving any success, as an incentive. Six subjects had to be replaced; four withdrew of their own volition, but not because of any expressed dislike of the Aid, and two were dropped on the recommendation of the instructors as they failed to make any progress. Cranmer reports two approaches to the use of the Aid. The first, exhibited by six of the subjects, used the Aid merely to detect and avoid obstacles in their path. The subjects using this approach reported the advantages of the Aid as being the ability to travel more quickly and confidently and the disadvantages as being the need for a long training period and the lack of any clear indication of a step down. The second approach uses the Aid to discover more about the surrounding environment and to form more useable concepts of it. These subjects praised the Aid from the standpoints of mobility, orientation and simple enjoyment of the experience of environment sensing and exploration. The only major criticism from the second group was the lack of a clear indication of a step down. The two approaches probably represent two levels of the same skill, the groups having differentiated themselves for reasons of ability or motivation.

Gissoni (1966), a blind person who uses the Kay Ultra Aid for all navigation, claims that it gives fuller and more useful information than any other aid. Swail (1966) found that while simple detection of obstacles presented no difficulty, it was not so easy to learn to react quickly under the stress of real travel conditions. He believes that while the Aid is probably not acceptable to all blind people it can be useful for those who are prepared to learn to use it and suggests that special schools, such as those which train the guide dogs and their owners, could be used.

Leonard and Carpenter found that blind boys using the Aid performed better in noisy unfamiliar streets but Elliott, Elliott and Roskilly (1966) found that after some training with the Kay Aid street navigation was somewhat slower than with the normal aid. Improvement was still obvious, however, and the difference in rate was satisfactory for most subjects as the comparison was made in areas where subjects were experienced in navigating with their usual aid.

2. Obstacle Courses: Blind people are trained to use the Aid and then tested on an obstacle course which is believed to demand the skills necessary in normal navigation with the Aid. Performance with the aid is compared with performance on the same obstacle course without the Aid, either by the same subjects with no aid or with their usual aids before they are trained to use the Kay Ultra Aid, or by a control group who have not been trained to use the Aid.

Leonard and Carpenter (1964) worked with two matched groups of boys within the age range 12-18 who were blinded early in life and used to navigating without artificial aids. One group was given training in the location and detection of obstacles and in street navigation using the Aid, while the other was given street navigation experience and training which concentrated on obstacle detection and navigation without an aid. Measures were taken of speed, obstacle detection and negotiation on several similar obstacle courses. At first boys using the Aids dealt more effectively with the obstacles but took longer to complete the course than the unaided boys. By the end of the experiment this difference had lessened. Leonard (1963) claimed that both groups improved, the boys with the Aid became faster by concentrating on essentials and the boys without the Aid became more accurate because they had learnt to cope with the types of obstacles used. In situations when outside noise was high the aided boys performed better than the unaided. During the street trials it was discovered that the Aid sometimes presented the subjects with confusing signals, stemming particularly from the large differences in the loudness of the note obtained from different kinds of surface, for different angles of incidence upon surfaces that reflect in a specular way and from rapidly approaching pedestrians. All but one of the boys would have liked to keep the Aid.

Elliott, Elliott and Roskilly (1966) reported that subjects used as their own control made fewer errors and moved faster when negotiating the course with their usual aid than with the Kay Ultra Aid. They also found this to be true with street navigation. The performance with the Kay Aid was, however, still improving and Elliott et,al, stated that the rate was reasonable for most subjects. Riley, Weil and Cohen (1966) also found that the number of errors made and the time taken to complete an obstacle course, designed by Mickunas and Sheridan (1962) for research on mobility with a cane, were greater when the subjects used the Kay Ultra Aid than when they used their normal aid, the cane. They comment that it is not surprising that subjects perform faster with the technique they have been using for years, but if the Kay device was a comparable navigational aid, one would have expected differences in time alone not in the errors made as well. The obstacle course used by these authors contained a large number of low objects and steps up and down. This may have biased the results in favour of the usual aid, the cane, which maintains more direct contact with the environment. Most of the subjects did not wish to replace the cane with the Kay Ultra Aid and considered that it would be useful as an obstacle detector but not as a navigational aid; this may be due to the emphasis of the training and the nature of the obstacle course.

3. Psychophysical Experiments: The quantitative measures of perception using the Aid obtained in simplified and highly controlled conditions. Leonard and Carpenter (1964) attempted a controlled study of the influence of texture differences on the judgement of distance. Seven boys were asked to judge the relative distance of a

concrete wall 54 inches from the aid and the following variables:-

1. A thick jumping mat giving a very weak echo.
2. A wooden trolley covered with a double layer of sacking.
3. A small tree branch.

The estimates of equality, obtained by averaging two judgements from each subject, were 50.2", 53.1" and 51.1 inches respectively. In all cases the variable gave a quieter signal than the wall and the estimate of equality was closer than the distance of the standard, indicating that the softer object is perceived as further than the harder one. This trend was most noticible for the variable giving the softest signal. This showed that even after four weeks training with the Aid the texture of the object altered perceived distance.

Elliott et.al. (1966) studied the ability of the subject to recognize when the object is two feet away from the Aid; both when the subject is moving towards a stationary obstacle and when an obstacle is moved towards a stationary subject. In both cases more than fifty percent of the estimates of each subject lay within two inches of the required distance and nearly all were within one foot. Recognition of different distances presented on a tape was high, as was recognition of differences in texture when only a few textures were presented.

4. <u>Determination of the background factors that predict success with the Aid.</u> Riley et.al. report that:-

1. age is not significantly related to performance with the Aid.
2. that hours of training were not significantly related to performance. However, as the measure of training used was the total of all hours spent using the Aid and did not examine the length of time spent on specific training tasks or in private practice, this lack of relationship has little meaning.
3. Performance with the subjects usual aid is related to performance with the Kay Ultra Aid.
4. A composite measure from the Pitch, Timbre and Tonal Memory sections of the Seashore Measures of Musical Talents (a test of auditory discrimination) was not significantly related to performance with the Kay device, but the score on the pitch subtest was.
5. Personality measures on the Marlow Crowne Desirability Scale (a measure of the need for social approval), the Flexibility Scale from the

California Personality Inventory and the Intolerance of Ambiguity Scale (Cohen, 1966) were all found to have a significant relationship to performance with the Kay Aid (Riley et.al. ascribe this to 'defensive inflexibility'). This was the background factor most highly related to performance with the Aid.

Summarizing these studies it would appear that:-

1. The Kay Ultra Aid for the blind is favourably evaluated by most blind people, although the older cane users of St. Dunstan's (Leonard and Carpenter, 1964) did not find it personally acceptable, and the cane users of Riley et.al. (1966) found it better for obstacle detection than navigation. The boys from Worcester (Leonard and Carpenter) who usually used no aid, found the Kay Ultra Aid personally acceptable. These studies suggest that the Aid will be personally acceptable to those blind people who are used to navigating without tactual contact with the environment and to dealing with complex auditory information, but not acceptable to those subjects who have come to depend on tactual contact. This conclusion can only be tentative as there were differences in training procedures in the above experiment and this, not the usual means of navigation, may be responsible for the

for the different subject reaction.

2. Performance with the Kay Ultra Aid is slower than that with the usual methods of navigation. This cannot, however, be offered as a criticism of the Aid as one would expect that an old established skill would enable more rapid navigation than a new one.

3. There are conflicting reports about differential amounts of error with the Kay Ultra Aid and other means of navigation. Leonard and Carpenter report less error with the Aid than without and Riley et.al. report more error with the Aid than the cane. The difference could be due to: different obstacle courses (Riley et.al. used a course designed to study navigation with the cane and hence probably weighted results in favour of it), the subjects' usual means of navigation (the boys studied by Leonard and Carpenter used no aid at all, and the subjects used by Riley et.al. used the cane) or to the differential training schedules. The large number of factors involved make evaluation of the differences impossible.

4. The Aid can be used as an obstacle detector alone or as an 'environment sensor'.

5. Fine discrimination and accurate obstacle detection are possible in simple situations,but not always

during the stress of movement or other complex situations.

6. Ambiguities can occur in the signal from the Aid, especially through changes in the loudness of the signal with changes in the texture of the object. This can bias estimates of distance.

7. No conclusions can be drawn as to the relative advantages of differential training procedures as there are no uncontaminated measures.

8. Personality measures of 'flexibility' are related to performance, rate of learning being slower in subjects exhibiting 'defensive inflexibility'.

9. Performance with the Aid is related to pitch discrimination as measured by the Pitch subtest of the Seashore Measures of Musical Talents, but not to Tonal Memory or Timbre discrimination measures from the same test.

The last two factors can be used in selecting potential users of the Aid but the relationship is not so great as to indicate that any large section of the blind population would be unable to use it.

Examining these results in the terms of the critereon suggested above we find that, on the whole, the Kay Ultra Aid passes the physical requirements and the general mobility requirements, but not the more rigorous of the mobility requirements.

Evaluation of another Aid for the Blind

The only comparable studies using another blind aid are those by Worchel, Byrne and Young (1963, 1966) on the optical Obstacle Detector (OD) developed by the U.S. Veterans Association. Obstacle courses were used to evaluate the aid, with each subject serving as his own control by performing the obstacle course with his usual aid initially, and with the OD after a short period of training. Overall the OD led to an increase in the time taken to complete the course with practically no gain in the ability to avoid obstacles. However, this generalization is misleading as those subjects usually using no aid made considerably fewer errors with the OD and were much slower, whereas those subjects usually using the cane or a Guide dog made more errors as well as taking longer to complete the course. Measures of personality indicate that subjects who are better psychologically adjusted are best able to use the aid.

Those subjects usually using Guide dogs expressed the greatest desire to keep the OD despite the deterioration of performance when it was used. Those usually managing without an aid, who showed some improvement in performance with the OD, had the least desire to keep it. The subjects rating the OD most highly were those who were normally the least mobile.

No direct comparison can be made between the OD and the Kay Ultra Aid as they have not been tested under the same conditions. It should be noted, however, that subjects who usually did not use an artificial aid were less interested in the OD and more interested in the Kay Ultra Aid than those who normally used artificial aids giving tactual information. It is possible that the less complex tactual display of the OD is preferred by those who are used to depending on the tactual information about their environment whereas the more complex auditory display of the Kay Ultra Aid is preferred by those accustomed to operating with the complex auditory information about their environment available to all. There was, however, a difference in training and in age in the groups examined with the Kay Ultra Aid and hence any such conclusion can only be tentative. It is supported by Riley et.al.'s discovery that cane users do not rate the Kay device highly, Leonard and Carpenter's discovery that the more mobile find the Aid more acceptable and Worchel et.al.'s discovery that the less mobile praise the OD. This trend probably stems from the need for more information of a complex nature by the more mobile and the requirement for little simple information by the little mobile.

To amplify a point made above, all these studies have used very small groups of subjects who have been blind for some considerable time, in some cases perhaps for more than 50 or 60 years. Each subject comes to an experiment with a lengthy learning period and usually considerable skill in the use of other techniques of navigation. The negative transfer from these other skills is sometimes mentioned and sometimes apparently never considered, and the effect on motivation is unconsidered and unknown. If these effects are relatively large, as they well may be, the results of such experiments can hardly be taken as indicating the relative superiority of different aids. This is a strong argument for using newly or temporarily blinded subjects. Worchel, Byrne and Young (1966, p.225) state:

> "Ideally, it would have been desirable to use a group of newly blinded subjects - some of whom, at random, would be trained on the use of the OD, others on the cane, others on the Guide dog, and finally, the remaining blind would be trained to move about the environment without any aid at all."

They believed that this was impractical and so selected from the blind population that was already available.

Blindfolded sighted subjects can be used instead of the newly blind. If this is done questions as to the validity of generalizing from the temporarily blind to the permanently blind are raised. Such questions can best be answered by an examination of the research into perception and spatial concepts of the blind and sighted.

Schlaegel (1953) summarized the early work on visual imagery in blind subjects and concluded from these, and his own studies, that so far as can be determined by introspection, visual imagery is available to subjects who have been able to see up to the age of about six years,but not to any extent in cases when blindness occured earlier. Worchel (1951) found a similar difference between the congeneitally and accidentally blind in ability to recognize forms, together with a correlation between age of blinding and ability to reproduce shapes. Worchel found that the blind regardless of age and blinding performed less well than sighted people at an orientation task when blindfolded in a situation where auditory cues were at a minimum. However, the task was such that the need for visual imagery was questionable and the explanation may lie in the use of kinaesthetic cues. Drever (1955) took four years as the cut off point between early and late blind and found that the late blind were sometimes better performers than the sighted and sometimes slightly worse, and that the early blind always performed less well in tasks that demanded some form of spacial imagery.

In summary, it would appear that while work with temporarily blinded subjects may not be directly applicable to subjects blinded early in life, it may legitimately be applied to the later blinded, any difference will be quantitative and qualitative. The temporarily blinded subject is as likely to be as highly motivated as the blind person who is satisfied with his present aid and there will be a more consistent pattern of motivation in the different experimental groups when blindfolded sighted subjects are used.

Even when temporarily blinded subjects are used there are difficulties in discovering suitable training programmes and developing criterea of performance for the different devices. Optimal conditions for training mobility skills may not prove to be optimal conditions for assessment. Some training schedules and some evaluative situations emphasize one mobility skill in relation to the others and caution must be used in generalizing. The differential usefulness of differing mobility devices in diverse situations will be interesting in itself and may lead to the conclusion that the different devices all have different roles.

Perceptual Constancies

One of the new developments in the Kay Ultra Aid is the large amount of complex information transmitted to the user. As discussed above, no *a priori* claims can be made as to the usefulness of such complexity so we must look to the evaluatory studies. In most of these the complexity of the information is reported to be an advantage, but there are also reports of ambiguities in the data stemming from this complexity; Leonard and Carpenter (1964) discovered that differences in texture can influence distance perception. No information is available as to the influence of the size of the object on judgements of distance, nor of the influences of the texture or distance of the object on size judgements. It is, however, quite clear that such differences do affect the physical output of the Aid, as does angle of regard (Kay 1964). These differences mean that constancies will have to be developed by users of the Aid if they are to react to the stable and fixed characteristics of the environment, while they move relative to them, rather than the continually changing signals these will produce from the Aid.

Constancy was defined by Day (1964) as "the tendency for the judgement of certain properties of objects to remain constant with variation of other aspects of the stimulus complex." Research in this field has traditionally concentrated on the influence of the distance of an object from the subject on judgements of size, with some lesser interest in: the brightness of objects under different illumination, the shape of objects under different angles of tilt, and on the influence of absolute distance from the subject on judgements of length. Recently there has been an increasing amount of work on other relationships.

Perceptual constancy in the Aid will be examined in this study, not only because the establishment of such constancies is essential if the Aid is to be functional, but also because such an examination may aid understanding of similar visual constancies. If this is to be done, past research into these constancies must be reviewed. The following review concentrates on work with size and distance judgements as these are the areas which are to be examined with the Aid.

Research into the constancies has been concerned with the influence of: the characteristics of the stimulus context, differing attitudinal instructions, the judgement task and methods of stimulus presentation on judgements of attributes of stimuli; and the developmental trends related to these. (Discussion of the developmental trends will be left until later in the chapter.) Work on size constancy has lead to the development of the Size-Distance Invariance Hypothesis, expressed by Kilpatrick and Ittleson (1953, p.224) in the following manner; "The retinal projection or visual angle of a given size determines a unique ratio of apparent distance", i.e., the subject perceives the size of an object to the extent that he perceives its distance accurately. The hypothesis has lead to further research.

Reviews of the relevant literature can be found in Vernon (1952), Epstein, Park and Casey (1961), Day (1964), Gogel (1954, 1965[a]), Baird (1963), Biersdorf, Ohwaki and Kozil (1963), Epstein (1963[a]), Tanaka (1966) and Smith and Smith (1966). An outline of the conclusions that can be drawn from these reviews follows.

Size constancy is known to be manifested in adults under normal viewing conditions with an increasing tendency towards overconstancy as the distance between object and subject increases. The amount of constancy exhibited decreases as the number of cues to distance (or at least to context) decreases, although a high degree of constancy is maintained even when only a few contextual cues are available, These cues may even take the form of linear drawing (Wohlwill 1962) which leads Smith and Smith (1966) to claim that all that is needed is an awareness of depth, not cues to the distance between the subject and object(s).

The amount of constancy exhibited is also determined by the experimental method used, those patterns giving rise to the highest degree of constancy in the adult are those in which constancy is exhibited at an earlier age. Aspects of the experimental design which influence the degree of constancy exhibited are; the attitudinal instructions, the judgement task and the nature of the stimulus presentation. (Baird 1963, 1965; Biersdorf, Ohwaki and Kozil, 1963; Epstein, 1963[a]; and Tanaka, 1966).

Varying the instructions to the subject affects his estimates of visual size. Four types of instruction have been explicitly defined, these are 'objective', 'perspective', 'apparent' or 'phenomenal' and 'projective'. Under normal conditions these give rise to overestimation, greater overestimation, verdical perception and under-estimation of physical size respectively. The different attitudes to size judgement do not affect judgements of distance or ocular motor adjustment, indicating that instructions influence size judgements without the mediation of changes in perceived distance. This means that the relation between size and distance perception must vary when the judgements are made under differential instructions, with the high correlation between size and distance, demanded by the Size-Distance Invariance Hypothesis, occurring only when objective instructions are given.

Different experimental conditions are related to instructional variables in different ways; judgements made with objective and projective attitudes depend on the visual cues available and on the distance between the comparative and standard stimuli; when other cues are removed assumed size of the object is an important determinant of estimated size under objective conditions, but not under projective conditions; under highly restricted viewing conditions instructions do not influence judgements. This means that if the stimulus conditions are appropriately altered a variety of instructions can yield the same kind of estimate and the same instructions can yield disparate estimates. Thus the minimum information needed to predict the nature of judgements in a constancy situation includes specification of both the stimulus conditions and the instructional variables.

Different psychophysical methods have been shown to evoke different responses, e.g., results tend towards the physical size of the initial variable when the methods of limits and adjustment are used, but results tend towards the middle of the stimulus series when the method of constant stimuli is used. More constancy is displayed when the visual angle changes and physical size remains the same than when physical size changes and visual angle remains the same. The differences between constancy judgements obtained from comparative judgements and, what Makino and Ueno (1963) called, single stimulus judgements (which were made with a single visual stimulus but had a comparative object held in the hand), were so great that they were led to develop the hypothesis that the different methods gave rise to different types of constancy. The single stimulus situation gave rise to higher constancy which was less influenced by changes in the observational conditions. Kuroda (1964) showed that the rate at which overconstancy replaces constancy varies with the method employed, the amount of increase being the largest with the method of magnitude estimation, followed by the method of transposition and finally by the method of adjustment.

Attempts to explain the influence of experimental variables show two general approaches; those that stress the external stimulus arrangements and those that stress the response bias set up in the subject as a result of the experimental variables. The latter can be seen as an attempt to relate the experimental influences to the research with attitudinal variables already discussed; the two approaches both predict much the same results and hence neither can be demonstrated to be superior to the other.

One way of dealing theoretically with instructional variables is to consider one to the exclusion of all others. Hence, it is suggested that: perception is mainly concerned with the visual world described by three dimensional geometry (Gibson, 1950, 1959); that some instructions are more natural than others (Joynson 1958); or that laboratory conditions may distort the normal relation between physical size and subjective responses (Carlson 1962). The primary role of an experiment in this approach seems to be to show which instructions give rise to a one-to-one psychophysical function between estimated and physical size. The existence and pre-eminence of this function is assumed _a priori_ on the grounds of a broader theory about man's relationship to the environment.

Makino and Ueno (1964) depart from this convention and develop the theory that when comparative judgements, which they claim to be those most influenced by observational conditions, are made, two polar attitudes operate; 'comparisons of occlusion', leading to judgements of visual angle, and 'comparisons of proportionality' leading to a physical size match and hence to constancy. They claim that judgements lie between these extremes according to the variations of conditions. Conditions favourable for comparisons of occlusion are, simultaneous comparison of objects with little separation of stimuli in a homogenous field with little illumination, viewed monocularly or through a reduction screen with fixation of the visual line and a retinal parallel gradient of the visual field. In opposition, conditions favourable to comparisons of proportion are; successive comparison of stimuli with wide angular separation, high illumination of an articulated field, binocular observation with free movement of the head and eye and a physical-parallel gradient of the visual field. The role of the gradient cues has been verified by Makino and Ueno (1964).

Smith and Smith (1966) make a similar claim that two processes of judgement are involved and add that there is no guarantee that all subjects will make the same type of judgement in any situation.

The unique relation predicted by the Size-Distance Invariance Hypothesis has been shown to be only one of the relationships actually discovered. This is probably due, in part, to the fact that the hypothesis had its origins in geometry and takes no account of subjective variables, such as, the possibility that different cues may be used for size and distance judgements, even when they are made in identical situations. Recent work has led to the rejection of the molar form of the hypothesis, which claims that perceptions of size and distance are uniquely related in all situations, but supports a more limited form which claims an invariant relationship between size and distance judgements with: objective instructions and immediate, spontaneous responses unmediated by cognitive deliberation; and when size and distance judgements are concurrent aspects of the same judgement.

Even though the Size-Distance Invariance Hypothesis has not been fully supported, research arising from it, and other related hypotheses, has been useful because it has, of necessity, promoted an examination of distance judgements under differing stimulus contexts, particuliarly in highly restricted viewing conditions when normal cues to distance are not available and when the objects subtend different retinal sizes.

One such area of research is that concerned with the 'equidistance tendency', i.e., the tendency to perceive objects as being the same distance from the observer in the absence of cues to the contrary. The ability of observers to make relative retinal size judgements with severe cue reduction, monocular observation and the successive or simultaneous presentation of stimuli can be incorporated into the Size-Distance Invariance Hypothesis only if we make one of the following assumptions: either apparent distance tends towards zero, or it is the same for both the standard and comparison objects. The first assumption is meaningless in the experimental situation involved, the second, however, which is the 'equidistance tendency', has amassed sufficient experimental support for Gogel (1965[a], p.161) to claim that it encompasses the following phenomenon:

"1. The equidistance tendency occurs between any visual inhomogeneities (between any contours or parts of a figure or surface).

2. The strength or effectiveness of the equidistance tendency is inversely related to directional separation (in any orientation).
3. The equidistance tendency occurs between objects viewed monocularly, or between objects viewed binocularly, or between objects some of which are viewed monocularly and some binocularly.
4. The presence of strong depth cues can reduce or eliminate the effectiveness of the equidistance tendency.
5. Under certain conditions, the equidistance tendency can modify depth perceptions resulting from cue systems such as binocular disparity and relative or familiar size.
6. The equidistance tendency can act as a resultant effect occuring between one object and a complex visual field."

Gogel claims that the equidistance tendency acts as a depth factor entering quantitatively into competition or agreement with other depth factors in the determination of a final apparent position of an object in depth.

Other work on distance judgements has been concerned with the influence of assumed size on judgements of distance under reduced conditions. Assumed size can be derived from two sources, relative retinal size and familiar size. Relative retinal size is a difference (or equality) in retinal sizes occuring from simultaneous or successive presentation of objects of the same shape: if the retinal sizes are different, a perception of depth between the objects will occur with the object having the retinally smaller size appearing the more distant; if the retinal sizes are the same, the objects will appear equidistant. A necessary condition for this cue to operate is that the two objects are assumed to be equal in size.

It has been questioned whether familiar size can be claimed to operate independently of relative size as most experiments confound the two. However, when the two cues are in opposition, responses are in agreement with familiar, and not relative size. It thus seems reasonable to conclude that the familiar size is an independent cue to relative depth and cannot be subsumed under the relative size cue to relative depth. The perception of relative depth deriving from both these methods can be said to be due to the relative values of perceived size and visual angle or perceived size per unit of visual angle (Gogel, 1964).

It was formerly assumed (at least implicitly) that the reason why familiar size is a cue to perceived relative distance is that it acts as a cue to perceived absolute distance. However, what little evidence there is available on judgements of absolute distance suggests that, although familiar size can influence judgements of absolute distance, intra-subject variability is very large and it is, therefore, unlikely that the influence of familiar size on absolute depth can account for its influence on relative size. Further, it can be questioned whether any measures of the influence of assumed size on judgements of absolute distance can ever be obtained as one cannot discount comparison with experience prior to the experimental situation. The difference between comparative and absolute judgements may be one of temporal and spatial separation of the standard and comparison.

This work on distance judgements has shown that the influence of differences in the size of the stimuli on distance judgements under restricted viewing conditions closely parallels the influence of differences in the distance of the stimuli on judgements of size, especially in those situations which give rise to visual angle matches. Retinal angle judgements of size are made in comparative situations when the objects are believed to be equidistant from the subject and the same type of match is given with distance judgements in the same situation when the objects are assumed to be of equal size. However, when we come to examine the amount of logical and experimental work concerned with size and distance judgements under conditions which demand constancy, we find that a large amount of such work has gone into defining and clarifying the term 'size' and has given rise to the distinctions of 'distal', 'real', 'apparent', 'retinal' and 'assumed' size, among others, and to a large amount of information about the role of stimulus context, but little comparable work has been done on distance judgements. There is even some confusion about the definition of distance constancy; early work by Purdy and Gibson (1955) and Smith (1958) defined distance constancy as the tendency, in a specific situation, for two parts to be judged consistent in extent with changes in the distance of the space from the observer.

Most of the experimentation related to this definition used bisection judgements. Over (1961) suggested an alternative definition, which is more closely related to the commonly accepted definition of size constancy. This states that distance constancy is the expectation that two objects at the same distance from the subject will be judged equal in distance despite differences in physical size. This definition will be used throughout the remainder of this thesis as it enables greater comparison between size and distance constancy and as the earlier definition may be better relabeled 'length constancy'.

The reason why less attention has been paid to distance constancy than to size constancy, and shape and brightness constancy, is probably because constancy was conceived of as a process which served to provide stability in our perception of objects and distance (unlike size, shape and brightness) is not considered to be an attribute of the object but of the environment in which the object is placed. The inclusion of distance as a legitimate constancy demands that the concept of the function of constancy be expanded to include the stability of our perception of all spatial attributes of the environment.

Work on size and distance constancy has continued to arouse interest since most of the reviews discussed above were written and the following studies, not discussed in them, are of interest. The areas studied are mainly those which were not immediately perceived as relevant.

Gogel, Wist and Harker (1963) modified the cues to perceived distance by an optical device which produced magnification or minification of the effective inter-pupillary distance (base) of the eyes. This device altered binocular cues to distance but did not affect monocular cues which were readily available to the subject throughout the experiment. Estimates of absolute size and distance were obtained from kinaesthetic adjustments; throwing darts the estimated distance and matching size by adjusting the lateral distance between aluminium rods held in the subjects lap out of sight. Subjects also made judgements of perceived relative size; the variable for the comparative judgements, separation of two black rods, was the stimulus for absolute size judgements and the standard for the comparative judgements, a black rectangle, was the stimulus for absolute distance judgements. The different interpupillary distance significantly affected estimates of perceived absolute size and distance but not perceived relative size. When absolute judgements were made increase in base produced longer distance judgements and larger size judgements. The complexity of the cues operating in this experiment makes any simple explanation of the results impossible but Gogel et. al. suggest that an explanation in terms of frontal and depth extents can account for the results. In disagreement with the Size-Distance Invariance Hypothesis the ratio of perceived size and perceived distance was found to be a function of both base and physical distance. The authors present this as evidence that the Size-Distance Invariance Hypothesis must include some parameters from the viewing conditions. The obtained difference between absolute and comparative judgements was taken as support for the claim that different processes are involved in the two types of judgement.

Over (1963) examined this difference between absolute judgements (those with a single stimulus) and relative judgements (those with a visual comparison stimulus) on estimates of both size and distance. Assuming similarity between absolute judgements of size and distance using the normal measurement scale, (which is a ratio scale) and the better known relative judgements he hypothesises that single stimulus size estimation in unrestricted viewing conditions should correspond to physical size and estimated distance to physical distance and that in restricted viewing conditions size and distance estimates should both be a function of physical size and physical distance. The results from the unrestricted viewing conditions support the hypothesis but not the results from the restricted viewing conditions. In the latter case both size and distance estimates departed from reality, as expected, with a change in either size or distance leading to a change in estimation of both variables (with high variance), but the ratios of size and distance estimations were not determinate. Over suggests the following explanation: when comparative judgements are made in highly restricted viewing conditions, the relevant information (the equality or non equality of visual angle) is provided in the visual situation, but in the single stimulus situation there is no explicit feature of the visual situation to which the stimulus can be related and the subject is forced to relate it to more subjective estimates (in this case estimates of the length of the room and the size of the object). As it is only when size and distance estimates are made with the use of a single set of criterea that determinate estimate ratios are expected, this accounts for the failure of the second hypothesis.

This study, like that of Gogel et.al., reinforces the claim that the Size-Distance Invariance Hypothesis needs further specification. But unlike Gogel et.al., Over suggests that the distinction between 'absolute' and 'relative' judgements is not as clear cut as is often claimed. The difference found by Gogel et.al. was probably due to the fact that relative judgements were obtained when both objects were observed with the same interpupillary distance, and were thus both subject to the same distortion of distance, whereas the absolute judgements were made under differing conditions of interpupillary distance which depart from normal experience, i.e., the difference between absolute and relative judgements can probably be best interpreted as due to differences in the cues available in the two situations. The lack of any differences between comparative and single stimuli judgements in the unrestricted undistorted situation supports this claim as such a situation provides a large number of potential comparison objects.

Epstein (1965) attempted to demonstrate that the results of his 1963[b] study, indicating a relationship between assumed size and perceived distance, did in fact demonstrate a relationship with perceived absolute distance, and was not just an effect of the visual relationships introduced by the use of the visual comparison objects, by repeating the original study using tactual measures of the size and distance of the coins. As in the original experiment mounted photographs of the dime, quarter and half dollar all having the same diameter were judged for size and distance under both monocular and binocular viewing conditions. Under monocular conditions the half dollar was located furthest from the subject and the dime the closest; the half dollar was judged to be the largest and the dime the smallest. No significant differences were found with binocular viewing. These results are in general agreement with those of the earlier study indicating that assumed size can influence judgements of distance even when there are no immediate comparison visual stimuli. It must be noted, however, that some comparison (that with past experience) was necessary for familiar size to alter judgements.

Gruber and Dinnerstein (1965) looked at the more direct relationship of known distance on phenomenal distance and discovered that knowledge of absolute distance influenced verbal judgements of perceived distance, but not the relationship between them determined by differencing the absolute judgements. Knowledge was provided by a thorough acquaintance with, including movements through, the experimental situation under full viewing conditions before the subject was asked to make apparent distance judgements in what was known to be the same situation under reduced viewing conditions. Two objects of the same size but at different distances were always present in the same situation. It was claimed that the obtained differences in judgement were due to perceptual and not judgemental changes as the subjects commented on perceptual differences which were contrary to knowledge. Thus, in a situation in which viewing conditions are highly restricted and two stimuli are present, visual angle matches can dominate physical size matches even when this is contrary to knowledge. The 'equisize tendency' would thus appear to act, as does the 'equidistance tendency', as one quantitative variable among many. Knowledge can lessen its effect but not overcome it.

Work by Gogel (1965[b]) on the 'adjacency principle' helps to explain this further and also to explain the distinction between absolute and relative judgements. He studied the influence of size cues on estimates of relative depth using cards with varying separation distances and showed that the dominant cues determining the perceived position of an object in a configuration of objects are those which occur between it and the objects closest to it, the influence decreasing as the distance between the objects increases. The work on equidistance tendency shows a similar trend for size judgements. The adjacency principle is still at a formative stage but it seems likely that this principle can be expanded to take in temporal as well as spatial adjacency. If this is done, it can be applied to the above explanation of the differences between absolute and comparative measures, as the cues that are most influential are those from the rest of the stimulus complex, i.e., from the 'closest' source. The operative cues in the absolute judgement situation are those from past experience or other more 'distant' cues. This would also account for the domination of the comparative cues over past experience in the Gruber and Dinnerstein study.

The above discussion leads to the conclusion that the differences between absolute and comparative judgements are quantitative rather than qualitative, However, this must not be interpreted as a rejection of any distinction between the different judgements. It is still a useful distinction and should be noted when the influence of stimulus context on size and distance judgements is examined as some variables will exert considerably more influence in the comparative situation than in the single stimulus situation and vice versa. Some of the factors operating in the comparative situation, which have been recently discovered, are discussed below.

Epstein and Franklin (1965) showed that variation in the size ratio of two objects is necessary to produce variation in perceived relative distance as measured by tactual and verbal judgements. Change in absolute size without change in the size ratio did not lead to a change in perceived relative distance. They also showed that the difference in shape of the two objects (a square and a circle) does not influence the results. They claimed that this queries Gogel's 1964 claim that the influence of relative retinal size on perceived retinal distance is due to an assumption of equal size as they claim that such an effect would not hold when the objects are different shapes. Gogel claims that the assumption of equality holds so long as the objects do not differ greatly in shape, and as the square and the circle are both simple geometrical shapes, in one sense, they do not differ greatly from each other.

A situation in which judgements must be comparative and which, in many ways, indicates the comparative basis of all constancy judgements is one in which the object stays still and the subject moves relative to it. Gregory and Ross (1964 a & b) have studied this by altering the rate of change in the size of a luminous circle on an oscilloscope until it appeared to be of constant size to a subject, who moved backwards and forwards on a swing in front of it. In the first study measures were taken with passive movement, under reduced viewing conditions and monocular vision. Greater constancy was found for movements towards the object than for movements away from it. The second study looked at the variables of binocular vs monocular viewing, the use of a fixation line across the center of the object and the availability of proprioceptive cues to movement from active control of the swing. Binocular vision produced higher constancy than monocular vision, as expected, so did the availability of proprioceptive cues. The fixation line had no significant effect on the amount of constancy evoked. The greater constancy evoked by forward movement is independent of the manipulation of other variables. This could be due to the individual's greater experience of forward movement than backward movement. The significant increase in constancy when proprioceptive cues are provided, suggests that the relationship between visual and nonvisual cues in constancy judgements is important and must not be neglected.

Van de Geer and Zwaan (1964) found that the size constancy index depends upon the angle of regard as well as objective spatial direction. Normal straight forward regard and horizontal direction yield higher constancy than the elevated regard and vertical direction. Prolonged monocular viewing conditions decreased the effect of the angle of regard. Van de Geer and Zwaan suggested that this occurs because size and distance constancy are learned mainly in situations in which horizontal viewing and straight forward regard are employed and that this learning is generalized, with some loss of skill, to the other situations. Thus when the subject is looking with an extreme angle of regard he is less able to use the available cues. Like the Gregory and Ross studies this study implies that past experience and proprioceptive cues both influence constancy.

Although both temporary and permanent monocularity have been shown to decrease the degree of constancy shown under reduced viewing conditions, Leibowitz and Dato (1966) found that neither tempory nor permanent monocularity influenced apparent size judgements under full cue conditions. This suggests that constancy can be mediated by a large number of cues, some of which are redundant for adults in full cue conditions. Leibowitz, Pollard and Dickson (in press) replicated these findings with adult subjects but found that monocular vision leads to a decrease in the amount of constancy shown by young children. As children presumably have a smaller range of cues available, this supports the claim that cue redundancy is responsible for the lack of deterioration in the adult subjects.

Dunn, Gray and Thompson (1965) specified some of the cues that can operate in monocular viewing of a two dimensional situation to give perception of depth and thus enable constancy to be exhibited. They showed that relative height in a picture frame can operate to give depth perception; objects higher in the picture were seen as further away when the subject saw the plane as a ground plane and closer when it was seen as a ceiling plane. Perception of the ground plane was the most usual. This influence of the frame can presumably operate in three dimensional situations and thus can be related to the finding of Smith and Smith (1961) that visual direction of targets was sufficient for veridical size judgements and nearly veridical distance judgements when the subjects were instructed that the object rested on the same ground as them. This indicates one comparative cue that is present in most single stimuli tasks.

Familiarity with the 'constancy phenomenon' has been found to have a direct relationship with the amount of constancy exhibited in size judgements under binocular viewing but not under monocular viewing (Pande, 1966). This is probably due to the absence of sufficient cues in the monocularly viewed situation to enable increased constancy to be demonstrated.

As noted earlier, the influence of some contextual variables have been ascribed to changes in attitude induced by the experimental variable (i.e., attitude is seen as an intervening variable). One such interpretation is Carlson's (1960, 1962) claim that the increasing tendency of overestimation of size with increasing distance of the stimulus is due to the establishment of a response bias. This hypothesis is reinforced by the discovery that perspective and objective instructions lead to overconstancy. Joynson, Newson and May (1965) suggested, however, that the increase in overconstancy with distance is a function, not of response bias, but of the nature of our sensory mechanisms. They claimed that overconstancy is limited to objects subtending angles of approximately two degrees or less, and that objects subtending greater angles are judged fairly accurately. It was suggested that foveal diameter is involved. Gubisch (1966) supported the claim that such overestimation is a function of the perceiving mechanisms. He claimed that the poor optical qualities of the eye which leads to the addition of a significant and constant amount of blur to the edges of images can account for this phenomenon. As the blur will add a fixed amount to the retinal size of all objects, the percentage overestimation will decrease with the increasing size of the image, reaching an insignificant amount when the object subtends more than two degrees. This means that when the judged objects are of the same size but at different distances, the further object will be overestimated more than the closer. The majority of constancy experiments have the standard closer than the variable and so this overestimation leads to overconstancy. If, however, the variable was the closer, the standard would be overestimated leading to underconstancy; this situation has not been examined.

This, then, is an explanation of the increasing overestimation of an object with increasing distance from the observer, and thus of the overconstancy exhibited with apparent size or ambiguous instructions, but does not explain the overconstancy exhibited with objective and perspective size instructions which is dependent on attitude and not distance of the object. These instructions make the subject aware of the need to compensate for the difference in distance and so the overconstancy may be due to additional compensation evoked by this awareness. The increasing overconstancy with distance occurs even when these instructions are given.

If Gubisch's hypothesis is valid, one would expect a relationship between the amount of overconstancy shown and visual acuity, because the minimal size providing accurate perception would increase as visual acuity decreases. However, as Carlson and Tassore (1963) suggested, this lack of acuity also reduces the cues to distance and hence should be expected to reduce constancy. The two opposing tendencies may explain why Carlson and Tassore were unable to obtain any consistent results.

To return to additudinal differences; work in differing experimental conditions, including differing instructions, has given ample evidence that an individual can judge either visual angle or objective size with a fair degree of accuracy when sufficient cues are available and when they are clearly instructed so to do, i.e., the individual can perceive two different attributes or properties of the size of the objects. Ono (1966) claimed that this indicates that two processes of judgement are involved which are based on different observational attitudes (this parallels Makino and Ueno's, 1964, and Smith and Smith's 1966 assumptions of two polar attitudes discussed earlier). Brief and ambiguous instructions such as those given in the early constancy experiments lead to judgements of physical size on some occasions and to judgements of retinal size on others. It is not clear whether one type of perception is preferred or more natural for a person or whether there are different preferences in different viewing conditions. There is evidence that, at least with adult subjects, the normal response is in terms of physical size when sufficient cues are available. Ono investigated the tendency of the subject to judge distal or proximal size, under restricted and unrestricted viewing conditions, when no specific instructions were given. A task requiring the subject to form his own concept of the stimulus variable was employed; the rate at which the subject learnt to associate with either distal or proximal size was determined for the two viewing conditions. It was found that under the unrestricted viewing conditions subjects learnt to associate with the distal size more rapidly than with the proximal size whereas under the restricted viewing conditions the reverse was true. The rate of association was assumed to be determined by the natural response to the object in the respective situations.

This interpretation of the constancy phenomenon in terms of two possible polar attitudes is very attractive especially as both the possible extremes of judgement can be said to be functional in their respective situations. If an individual is to be able to manipulate his environment, he must be able to perceive a stable environment which is not altered by his movement within it or by movements of parts of it relative to him. One would, therefore, expect that when a subject is asked to judge size or distance in a situation which closely parallels the everyday environment he will judge in terms of the objective attributes of the object. By contrast, when the subject is placed in the artificial situation in which no cues to objective size or distance are available one would expect him to judge in terms of the sensations immediately available, i.e., those of visual angle or proximal size and distance. The discovery that instructions do not alter responses in highly restricted viewing conditions while they do in less restricted conditions further indicates that the proximal judgement is the only possible response in this situation.

The more complicated situations, and those of most interest to the investigator of the constancy phenomenon, are those in which limited visual cues are available to the subject. As there is a large amount of redundancy in the relevant cues for the adult, considerable restriction of visual cues can occur without a significant departure from constancy. When fewer cues are available the judgements tend towards the proximal size of the object and complete visual angle matches are obtained when all cues to distance or size are removed. Departures from constancy which are not in the direction of proximal judgements can be explained by the physiological mechanisms (Gubisch, 1966) or to overcompensation due to objective or perspective instructions. It would therefore, appear that both attributes of the object play a role in determining the subject's response. There is a greater tendency to objective responses because of its practical applications and because objective judgements are robust in relation to the removal of cues.

Ono (1966) and Makino and Ueno (1964) suggested that these two processes of judgement are based on different observational attitudes. This involves an intellectualistic and partially conscious interpretation of constancy which is inappropriate in the light of the discovery reported above, that judgements depart from constancy in restricted viewing conditions even when such judgements are contrary to knowledge. Other discoveries, to be reported later, that constancy has been demonstrated in the lower stages of phylogeny and ontogeny are also inconsistent with such claims. To avoid such an interpretation the author prefers to ascribe the two processes of judgement to two opposing perceptual sets. Such a set is a state of definitely directed readiness in the subject conditioned by the given situation; the set to objective equality being developed in the full cue situations and the set to projective equality in the minimal cue situations. In the intermediate situations neither set is fully developed and the response is determined by the opposing forces operating in this ambiguous situation.

This bipolar interpretation of constancy can account for the differences stemming from the experimental method as well as stimulus context and instructional variables. The greater constancy shown in single stimulus judgements as opposed to comparative judgements can be explained by reference to the two polar sets. First by claiming that the comparative situation places more weight on the set to projective equality by presenting the basis for such a match to the subject. Secondly, the greater stability of the single stimulus situation may be due to a reduced possibility of the introduction of extraneous cues which would upset the balance between the polar sets. (This emphasises the purely quantitative basis of the differences between the judgements évoked in the two situations.) The tendency for the point of subjective equality to be biased in the direction of the initial stimulus will be due to the fact that the initial stimulus will approximate either objective or projective equality and will thus reinforce the appropriate set. When the visual angle changes and the physical size remains the same, we get higher constancy than when physical size changes and the visual angle remains the same. The former will reinforce the set to objective equality and the latter the set to projective equality.

The above discussion has been concerned with the situations in which no instructions are given to the subject. This is rare in recent experimentation, which has attempted to control the attitude of the subject and to specify the criteria to be used in making judgements. Such experiments have been useful as they have shown the role of attitudinal variables in determining constancy judgements, but it is now time to return to the natural situation, making use of the knowledge obtained.

How does the Size-Distance Invariance Hypothesis relate to the above discussion and recent research? It has been noted increasingly during recent studies that the hypothesis needs redefinition to restrict it to those situations in which it is applicable, Stress has been laid on the fact that it does not apply in all instructional conditions. It can be claimed, however, that it is not the hypothesis itself that needs redefinition but merely the interpretation that has often been placed on it. It is usually assumed that the hypothesis demands that the ratio of estimates of the size and distance of objects must be invariant when they are made in the same situation. This assumption is not valid; the hypothesis claims only that the perceived size of the object is determined uniquely by the proximal size and perceived distance and not that behavioural estimates of the size and distance of an object bear any particular relationship to each other. It is not claimed that the subject is consciously aware of the distance of the object. The behavioural estimates of size and distance are both influenced by the polar sets and hence it is only with unrestricted viewing conditions, when both judgements are made under the same instructional conditions, that one would expect to find a high positive relationship. Even in such a situation it is likely that different cues are used for the different judgements, especially as distance estimates are less dependent on secondary cues. With highly restricted visual situations both judgements will be expected to tend towards the visual angle and thus a high negative correlation between these variables will be expected in such a situation. This has been frequently demonstrated and labelled the Size-Distance Paradox by Gruber (1956); if the above interpretation is correct, this label is no longer appropriate. When limited visual cues are available, it is probable that different cues will determine the behavioural responses to size and distance and, the opposing sets being differently weighted, this would mean that one could not expect an invariant ratio of size and distance estimates.

In this review and discussion we have concentrated on the influence of differences of size or distance on the judgements of distance and size respectively as these are the areas in which most research has been conducted. However, it is predictable, from an examination of the characteristics of vision, that other variables will also influence size and distance unless constancy is established. Little research has been conducted with these other variables, but that which has been published should be examined to determine whether the mechanisms involved are the same as those in the size-distance relationship.

Brightness of the stimuli has been shown to influence both size (Robinson, 1954) and distance judgements (Coules, 1955) when the stimuli are judged under reduced conditions. Objects are judged to be equal when stimuli of greater intensity subtend a smaller angle than stimuli of lesser intensity.

Work on the influence of differences in hue on size and distance judgements has been more extensive (for a review see Over, 1962[a]) but is of limited value as there has been no attempt to control for brightness. Over (1962[a]) corrected this deficiency and found, as predicted from chromatic aberration, that objects subtending the same visual angle and of the same luminosity, but of longer wave lengths, judged under reduced viewing conditions, were judged to be both larger and closer than the stimuli of shorter wave lengths.

No studies have been conducted to measure the influence of these variables under unrestricted viewing conditions and so there is no experimental evidence that constancy is demonstrated in such conditions. However, personal experience and the ability of individuals to react to such objects during normal activities indicates that constancy is the normal reaction in such situations. Further indirect support for this claim comes from a second study by Over (1962[b]) in which he showed that the influence of size and distance on judgements of brightness closely parallels the influence each has on the other. Measures were taken under reduced conditions and, as expected, size and distance had some influence on all judgements and subjects given projective, rather than objective, instructions showed greater change in the expected direction.

The above result indicated that there is a reciprocal relationship for size, distance and brightness such that when judgements of any one of these attributes are made, in restricted viewing conditions, when the judged object varies in one of the other attributes, the judgements will depart from objectivity in the direction of the associated alteration of the sensory input. When judgements are made in a full cue situation, the objective response will be given. The research on the effects of hue changes on judgements of size and distance indicate that hue shares this reciprocal relationship and thus that this relationship may hold for all variables which influence the physical input, to the subject, on which the judgements of other variables are based. If estimates of equality of one of these variables is demanded when the objects to be judged are not equated in one of the other variables, the subject has two possible responses, one of which is based on equality of the sensory input on which the judgement is based (projective response) and the other is based on the equality of the physical objects on this variable (objective response). The response made will depend on the perceptual set which the total situation establishes. In high cue conditions this will lead to objective responses, in minimal cue situations to projective responses and in medium cue situations the two opposing sets will both influence responses, their relative strengths being dependent on the amount the visual situation is restricted, with the set to objective equality being dominant.

As secondary cues develop later are less strongly related to the judged variable (the covariation on which they are based is never complete) and more readily disturbed by changes in other variables; judgements which depend on such cues will more readily depart from constancy as the set to projective equality will be stronger. This readiness will, however, also be influenced by the number of such cues available, their reliability and the nature of the variable which is not judged. Changes in variables which alter the sensory input on which judgements of another variable are dependent will influence such judgements more. This effect will be greater if they provide a proximal match in which the two variables cannot be differentiated, under minimal cue conditions. Such changes will emphasize the set to projective judgements, both by reinforcing this set and lessening the power of the set to objective judgements. Those judgements based on cues which are little influenced by changes in other variables will be little affected by the changes in such variables as there is little or no weakening of the set to objective equality and little or no strengthening of the set to projective equality. If more than one variable is changed at once, the effect such changes have on the relative weights of the sets will be additive. The influence of changes in the stimulus context will, of course, be dependent on the ease with which these changes can be detected.

There have, as yet, been no studies of the more complicated situation in which two or more attributes of the stimulus context are varied while another is judged. If the subject is to respond to the stable attributes of the environment constancy must be effective even in such a situation and hence research in this area could greatly aid our understanding of perception.

The studies by Gregory and Ross (1964[b]) and Van de Geer and Zwaan (1964) which demonstrated that non visual cues (in these examples proprioceptive cues) can influence constancy, were examples of intersensory interaction, i.e., the effect of stimulation of one modality on perception in another modality. As can be seen from this definition, the areas of research involved in the examination of the constancy and intersensory interaction phenomenon are not very different. Constancy is concerned with the maintenance of judgements of one attribute of a stimulus with variation of other attributes of stimulation within the same modality, while intersensory interaction is concerned with the alteration of such judgements with changes in the action of other modalities or senses. This difference in emphasis can be traced to a difference in the role of the non judged variable; constancy is concerned with changes within the same modality as the judged variable and so the changes alter the sensory input on which the required judgements are based. Intersensory interaction is concerned with changes in another modality which does not alter such sensory inputs. If, however, the objective (constant) response is seen as the normal response, as in the earlier discussion, research into constancy can be seen as being concerned with essentially the same phenomenon as that intersensory interaction. Constancy differs from intersensory interaction chiefly in the availability of an alternative response set and thus has an expected direction of judgement change. The similarity of the two fields suggests that the research into intersensory interaction could aid our understanding of the breakdown and maintenance of constancy.

Reviews of the literature on intersensory interaction can be found in Wilson (1965) and Kravkov (1966). Much of this research has attempted to explain this interaction by hypothesizing physiological or sensory mechanisms. Wilson (p.47-48) suggested, however, that there are at least four explanations which are required to account for the results of the different experiments in the field; only two of which are physiological:

"1. Heteromodal stimulation may facilitate detection performance by raising the general arousal level of the observer."

"2. Heteromodal stimulation may facilitate detection performance by reducing uncertainty about exactly when the signal is likely to occur."

"3. Heteromodal stimulation may inhibit detection performance by distracting the observers attention from the task."

"4. Heteromodal stimuli may give rise to a sensory interaction by providing the observer with a set of clearly perceived cues to which he can in some way relate his responses when the primary judgement task is unstructured or ambiguous."

The first three explanations are concerned with detection and are thus not related to constancy, but the fourth is directly relevant to the failure of constancy as the subject is placed in a situation which is both ambiguous and unstructured when he is commanded to judge equality of one variable in a restricted situation in which other variables are changing. Wilson demonstrated such intersensory interaction and discovered that, in the absence of reinforcement of objective responses, the effect of the non judged variable was greater when the subjects were less able (or less inclined) to discriminate real differences in the judged variable (or they showed less confidence in their response). He found that this change was related to personality variables as measured by the Maudsley Personality Inventory. Generalizing from these results with intersensory interaction to the phenomonon of constancy leads to the hypothesis that greater breakdown of constancy would occur when the subject has less confidence in his response. Confidence in judgements will also decrease as judgements depart from projective responses. When the set to projective equality is completely dominant, judgements will be made confidently. As the set to constancy is stronger than the set to projective equality, one would expect that there will be a more rapid decrease in confidence as judgements depart from projective equality than as they depart from objective equality. The ambiguity of the situation stemming from the opposing sets will aid the breakdown of constancy and control the direction of change.

Support for this hypothesis can be found in the claims of Cohen, Hershkowitz and Chodack (1958), Lambercier (1946) and Piaget and Lambercier (1943) among others, that the area of uncertainty associated with judgements in a situation demanding constancy is a more sensitive measure than the constant error, especially when developmental trends are being examined.

The Development of Perceptual Constancies

In this discussion of constancy the perceptual set to objective equality has been accepted as the dominant of two polar sets without questioning its origins. Before we proceed any further, however, we must examine this question: is this capacity to abstract the invariant aspects of an object innate or learned? The research discussed above has shown that familiar size can play a significant role in determining the response and that forward movement and horizontal and direct regard provide for greater constancy than backward movement and vertical and indirect regard. This suggests that experience does play some part in determining constancy. There have also been studies which are directly concerned with this question. An examination of the relevant literature follows.

The claim that constancy is the result of experience with objects has led to research into the developmental changes in perceptual constancy. It predicts that constancy increases with age and that lack of constancy should be characteristic of the very young. The less extreme claim, leading to very similar research, that such experience is essential for the development of constancy as exhibited in the adult, predicts only that there should be some increase in constancy with age, particularly in those situations in which visual cues are restricted. It does not predict complete lack of constancy in the newborn child, something which it is impossible to measure at present.

Research into developmental changes in constancies has been well reviewed in Vernon (1954), Wohlwill (1960), Gibson and Olum (1960), Gibson (1963) and Smith and Smith (1966). Most of the work has been done on size, length, shape and brightness constancies, but the following discussion will be biased in favour of size and distance constancies as these are the fields directly related to the research in this thesis.

Attempts to study the developmental aspects of constancy have to overcome extremely difficult problems of control and interpretation. This is particularly true with research on infants, but even with older children the number of variables that may influence the results is large (see Gibson and Olum). Any one of these may produce different effects at different stages of development. However, a general summary can be made. Some constancy appears very early in life, probably by the end of the first year. Constancy may occur earlier with objects within the range of the child's mobility and under conditions in which constancy is enhanced in the adult (e.g. serial presentation of the variable, particularly with simultaneous presentation of the complete series, and a short distance between the standard and the variable). In such situations constancy is complete by five or six years of age. There is further improvement throughout childhood and adolescence in the more impoverished situations and in the interval of uncertainty, or difference limen associated with constancy judgements, even in high cue situations. The rate of development is determined by chronological, not mental, age indicating that it is mediated more by experience than intellectual ability.

It would thus appear that the younger child requires a greater variety of cues than the adult in order to maintain invariance in his perception. Further, the discovery by Denis-Prinzhorn (1959) that children show a greater correlation between size and distance estimates, suggests that similar cues are used for both types of judgements, probably the more direct and physiological cues. These claims obtain support from the work by Leibowitz, Pollard and Dickson (1966) which showed that loss of binocularity and increased subject-object distance, in unrestricted viewing conditions, causes a loss of constancy in the child but not in the adult. Further support comes from Wohlwill (1962) who found that, when two dimensional drawings were used, children were more influenced by alterations in perspective than were adults. This could be due to greater dependence on a smaller number of such "secondary cues" to distance.

Makino (1965) showed that although adults were not influenced by marked skewing of the comparison series, children were. He suggested that the developmental problem of perceptual constancies is in essence the problem of whether the comparison series has different effects over age. He stated that the change of perceptual constancies over age is not found under conditions such that children, as well as adults, can grasp the whole of the comparison series. Pratt (1950) showed that psychophysical judgements fluctuate with the scale only when there is some ambiguity i.e. when the field is only partly structured. Makino's results thus suggest that while adults have highly structured and stable perception even under the ambiguous constancy situations, such a situation is still highly unstable for the child. This is confirmed by the differences in the area of uncertainty found in children of different ages.

The above evidence establishes that there is some increase in constancy over age but does not indicate anything about the reaction of the naive individual. Working from the assumption that the reaction of a naive individual was that of a retinal size match, Piaget and Lambercier (1951 and 1956) conducted experiments in which subjects of different ages were instructed to make projective size matches. At no age were projective size matches made and a U shaped developmental trend appeared. The 10 to 12 age group performed worst, and the 7 to 8 year olds the best. Piaget and Lambercier suggest that this is due to less interference from the physical size match in the younger children and a greater capacity in the adult to abstract the relevant judgement from the complex of cues. This explanation can be rephrased in terms of the opposing perceptual sets suggested above. The set to projective equality was still dominant in the younger children but had been replaced by the set to objective equality in the middle age group. The adults had obtained sufficient conscious control over the response sets partially to overcome the set evoked by the stimulus context.

Braine and Shanks (1965[a]) attacked the problem of size conservation in illusions, such as the ring illusion, and related this to all work on conservation or constancy. They asked if the results obtained in constancy experiments were a function of the ambiguous questions offered in them. This work has close parallels with the research into attitudinal variables and constancy in adults. They examined this by defining the question more finely, asking both the following questions; "which is really bigger?" and "which looks bigger?" They found little difference in the judgements evoked by the two questions as nearly all children under seven tended to construe any question containing the word "bigger" as demanding a projective size response. (The ring illusion evokes projective responses to a later age than does the constancy situation as constancy has been shown under high cue conditions at five or six.) Braine and Shanks next attempted to determine, by giving feedback to the subject after each response, whether the failure of the different questions to evoke different responses was due to an inability to distinguish between objective and projective size or merely to a failure to associate the different wording of the questions with the alternative responses. They discovered that when reinforcement is given, most children are capable of a distinction, which is not task specific, between objective and projective size by the time they are five years old. The ability to make this distinction increases rapidly after a zero point at about three years of age. Similar age trends were found by the same authors (1965[b]) in shape conservation.

These results suggest that the emergence of constancy is related to the development of a general distinction between the objective and projective properties of objects. Before such a distinction can arise the individual must have some capacity, either learned or innate, to make constancy judgements. As the age trends discussed above are consistent with the development of size constancy, this suggests that this capacity increases with age. This does not mean that constancy is necessarily a learned phenomenon: it could be claimed that it is innate but not actualized until the child is made aware, by experience or maturation, of the distinction between physical and proximal size and of the adaptive nature of the physical size judgements in manipulating the environment. The existence of constancy in the lower animals (e.g. Gunter, 1951) has been claimed as support for this interpretation. The interpretation based on experience is still, however, the more attractive of the two.

The developmental trends are consistent with the hypothesis that constancy is based on two opposing perceptual sets. Experience with the environment changes the relative power of the two response sets. The set to objective equality takes dominance over the set to projective equality at about five years, the time when children learn to distinguish between the two possible judgements of equality. The number of available cues to size and distance increases concurrently with experience and as the situation becomes more highly structured, the set to projective equality becomes even less powerful. This increasing dominance of the set to objective equality is shown by Smith and Smith's (1966) discovery that seventy per cent of the children and thirty three per cent of the adults they examined, made visual angle matches in the same situation.

What aspects of experience are responsible for these developmental changes in constancy? An examination of the Theories of perception reviewed in Gibson (1963), Allport (1955) and Natadze (1966) together with that of Taylor (1962) shows that all theories which admit some perceptual learning, and these are in the majority, claim that movement within, and manipulation of, the environment is a prerequisite for the formation of constancies. It is believed that it is only through such experience that the individual can fully develop the capacity to respond to the invariant aspects of the environment. This agreement is more notable as the theories differ in the emphasis they place on the role of experience in determining perception. One extreme is represented by Taylor, who takes an empiricist position and claims that no part of perception is innate and that behaviour is empirically prior to perception. At the other extreme is Piaget, who claims that the infant has immediate perception of the reality and permanence of objects but must learn by experience which stimuli possess these qualities characteristically. These theories also differ in the perceptual mechanisms which they claim are responsible for the maintenance and development of constancy. No theory has been able to overcome the problem of describing a non-intellectual unconscious mechanism which can perform the function of "taking of the situation into account" which is seen as the basis of constancy. Natadze suggests that the concept of perceptual set can overcome this problem. This supports the author's interpretation of the phenomenon. As the establishment of such a perceptual set is also dependent on experience, this interpretation of the basis of the phenomenon does not decrease the likelihood that those aspects of the above theories, concerned with the role of movement are valid. Evaluation of such claims can be answered only by experimentation. As the theories do not restrict the role of movement to the development of constancies, the review of the relevant literature will also include other research into perceptual learning. Before the results of this research are examined, the methodological difficulties involved, which are numerous, should be examined. The role of a new perceptual instrument, such as the Kay Ultra Aid for the blind, in such research is also examined.

Perceptual Learning

Most theories of perceptual learning are poorly defined and so there is little research specifically related to them. Instead, studies examine general problems such as the genesis of perception, the role of experience in determining subsequent perception and the influence of specific practice on perceptual discrimination. These are separate issues and evidence related to the last two problems is not relevant to the first, despite frequent claims to the contrary. To examine these problems we need measures of perception from naive and perceptually immature subjects. Such measures usually depend on our ability, or lack of ability, to evoke responses, which we believe to be based on perception. Such measures are difficult to obtain from immature subjects, expecially in the higher animals, as the young lack sufficient motor co-ordination to make any appropriate responses. By the time the human infant has sufficient maturity to be tested he has had a large amount of perceptual experience and is no longer naive. In an attempt to overcome this difficulty the methods outlined below have been developed.

1. Studies in perceptual deprivation which is either experimentally determined and controlled or is naturally occuring. The former is employed mainly with animals and the latter is mainly concerned with men who have been born blind, and some of whom have obtained vision later in life. Reviews of much of this work can be found in Gibson (1963), Postman (1963), Epstein (1964), Wohlwill (1966) and Gregory (1966).
2. Studies of the enrichment of the natural environment. This research, which is limited, is reviewed in Gibson and Olum (1960), Gibson (1963), Postman (1963), and Wohlwill (1966).
3. Studies of perception in the naive animal and in the human infant. For reviews see Gibson (1963), Epstein (1964), Kagan and Henker (1966) and Wohlwill (1966).
4. Studies of changing perception in the developmental animal. Research in the change in constancy over age dominates this field. For reviews see Wohlwill (1960), Gibson and Olum (1960), Kagan and Hunter (1966) and Wohlwill (1966).
5. Experimental variation of relevant stimuli during early learning. For reviews see Postman (1963), Epstein (1964) and Wohlwill (1966).

6. Study of adaptation to distorted and displaced vision. Smith and Smith review the work until 1962. Gyr, Brown, Willey and Zivian (1966) and Wohlwill (1966) review the more recent work.

7. Study of adult learning of a new perceptual skill. Taylor (1966) has studied the learning process resulting when blindfolded sighted individuals are forced to use audition for the perception of obstacles.

However, none of these methods is very satisfactory. Studies of experimentally controlled deprivation and enrichment of perception in the naive animal have, of necessity, been performed on subhuman animals. Generalization to human perception is questionable, expecially as animals at different phyolgenetic levels have been found to give slightly differing results. Other criticisms of these methods rest on the fact that the differences may be due to destruction or lack of maturation of the physiological mechanisms involved, or of the subjects inability to make appropriate responses, rather than the perceptual processes themselves. Deprivation studies with human subjects have been limited to cases in which the deprivation occurs naturally. There are many uncontrolled variables in such studies, e.g., in those studies with subjects who achieve vision late in life there will probably be some transfer from non visual perceptual skills and concepts already established by the subject. Developmental changes found may be due to the maturation of physiological mechanisms, or to differences in the communication skills available to the subjects at different ages, rather than to the influence of experience on perception.

Changes in perception, stemming from experimental manipulation of relevant stimuli at an early age or from adaptation to alterations in the nature of stimuli available to the adult subject, establish only that the human visual system is flexible and capable of adapting so as to operate successfully in the changed environment. They do not necessarily demonstrate anything about the origin of perception or the nature of normal perceptual learning in the infant, if such learning exists. However, they can, and do, give us information on the relevant variables in such adaptation and throw some light on the interaction between proprioceptive and visual sensations. This information may well be applicable to early learning and, at least, suggests areas of useful research.

Taylor's research into the learning process of the mature subject faced with a new perceptual system may more closely approximate the initial learning processes than the other research. However, there is still the possibility of transfer, both positive and negative, from the usual methods of space perception. There is also the possibility that the skill, auditory detection of obstacles, is not entirely unlearned. The appropriate cues have been available to the subject throughout his life even if he has never had to depend on them before.

A blind aid presents the subject with a learning task which is probably more like that faced by the infant. He is faced with a set of signals which he has to learn to relate to the environment and to structure in such a way that he can stabilize his awareness of the world. This task still differs from the original learning task, as the subject has already developed a concept of the nature of the environment and is highly skilled in using other means of sensing this environment. There will almost certainly be some transfer, both positive and negative. The task may also differ to the extent that perception is found to be innate, in that the new symbols are arbitrarily related to the environment and sometimes, as in the relation of pitch to distance in the Kay Ultra Aid for the blind, are even in opposition to the relationship presented by the normal perceptual mechanisms. Thus any attempt to relate learning with this aid directly to perceptual learning in the infant, assumes that there is no innate basis to perception, a dangerous assumption held by few people today. It also assumes that there will be no transfer from past spacial concepts, another dubious assumption. However, a study of the nature of the learning process with the aid, especially when examined in relation to the other work on perceptual learning, may throw much light on early perceptual learning. Such knowledge will also be of use in developing training techniques for this and other perceptual aids.

Because of the unsatisfactory nature of these experimental techniques, few conclusions can be drawn about the nature of perceptual learning. A quick summary of the results is given below with a fuller expansion of the role of movement on perceptual learning because of its hypothesized relationship to the development of constancy and its applicability to future training with the Kay Aid.

The literature leads us to no clear cut decision about the genesis of perception but suggests that different aspects of perception will demand different explanations. The naive animal appears to have a fairly wide repertoire of behaviours, such as avoidance of the deep side of the visual cliff, which are assumed to be dependent on perception. Deprivation studies give no consistent pattern of results. Deprivation of patterned light has only a slight effect on orienting ability in rats, who are not dependent on vision. Higher animals, e.g., cats and monkeys, are influenced by such deprivation. Studies with the blind have shown that individuals who lose their sight after about four years of vision, differ from the congenitally blinded in their concepts of, and ability to manipulate, the spatial world, Those blinded late in life differ little in this area from the sighted. This suggests that these early years play an important role in perceptual development. This claim is supported by studies with congenitally blind adults who have been given vision by operations to remove cataracts; these subjects have meagre ability to organise the sensations made available and take a long time to learn some aspects of this skill.

<u>The Role of Movement in Perceptual Learning</u>

Change in perceptual skills within the developmental process can be seen most clearly in the development of visual constancies discussed earlier. Enrichment of the environment and modification of relevant variables in perception can lead to alteration of perceptual skills, indicating that experience can affect subsequent perception. Studies of adaptation to distortions and displacements of the visual field have found that while some adaptation does occur in humans, except to time delay, there is little adaptation in animals lower than man. Early studies by Kohler and others discussed in Smith and Smith (1962) suggested that movement is important to successful adaptation. Later work, until the middle of 1965, is reviewed in Wohlwill (1966). Wohlwill relates this work to studies of attentional mechanisms and the role of reinforcement and suggests that a systematic analysis of the role of feedback, in its various forms, may help to integrate some of the seemingly disparate problems in this field. He claims that what is essentially being studies in sensorimotor adaptation is the artificial induction of conflict between two separate, but normally correlated channels of sensory information, and that adaptation effects are in the relation between these two channels rather than in any particular channel such as vision. (Smith and Smith claim that the adaptation is motor.) Wohlwill suggested that any information with respect to the altered state of the system will serve as the basis for adaptation, the best source being that provided by reafferance, but with kinaesthetic and cognitive feedback also serving. He claimed that the nature of the feedback will affect the course of learning, as will the individuals prior reliance on the information provided. These factors may well be different for different intersensory and sensory motor systems. Furthermore, he notes that research, such as that of the Russian investigators (Zaporoshets 1965), suggests that the role played by the different types of feedback itself varies as a function of development. Finally Wohlwill questions the use of the differential aftereffect (DAE) as a measure of adaptation, because evidence from Taylor (1962) indicates that a subject can learn to change to and from distorted vision without any aftereffect.

Harris (1965) offered another full review of the work with prisms and concluded, in agreement with Smith and Smith, that adaptation is primarily proprioceptive. He claimed that activity gives rise to an awareness of discrepancy between the visual and proprioceptive senses which leads to changes in the proprioceptive awareness because proprioception has been shown to be flexible while vision, contrary to belief, is remarkably stable.

Research published since Wohlwill's and Harris's reviews supports the claim that movement affects adaptation because it is one means of obtaining information about the conflict between the proprioceptive and visual senses. It also questions the claim that adaptation is solely proprioceptive and provides additional evidence that the DAE is a questionable measure of adaptation. Despite the last discovery, the DAE is still the most commonly used measure.

Coren (1966) examined the effect of the amount of information available during a pointing response while wearing displacing prisms, by constraining the arm in a tract or leaving it free. Significant adaptation occured for both conditions. Subjects from the unconstrained condition showed significantly more adaptation than those from the constrained condition. Howard, Craske and Templeton (1965) and Templeton, Howard and Lowman (1966) report that passive movement can give rise to adaptation when motivation and opportunity to resolve the conflict is available. This is contrary to the results obtained by Held and associates, reviewed in Held and Freedman (1963), in which no adaptation was found with passive movement of the hand. An experimental difference was the demand, in the Templeton et.al. studies, that the subject make a decision on the basis of the perception of their passive hand while it was in motion, i.e., the subject had indirect control over the hand by verbal communication with the experimenter and was given feedback as to the result of the decision. No such information was provided by Held and associates. The lack of adaptation in the latter studies can therefore be related to the low level of information available to the subjects.

Singer and Day (1966[a] and 1966[b]) examined the relationship between the test phase of the experiment and the period of exposure to the displaced vision, together with the role of active and passive movement and spatial judgements during the exposure period. They found that; when the responses in the test and exposure phases of the experiment were dissimilar, less aftereffects were demonstrated; active and passive movements did not differ significantly in the amount of aftereffect shown, but the presence of spatial judgements increased it. Singer and Day (1966[b] p.70) suggest that the aftereffect is due to motor learning from the alteration of the relationship of visual and proprioceptive cues and claim that "this learning process is aided by judgemental activity rather than by active muscular involvement of the optically displaced limb" as when judgements are made relative to a reference standard, then this discordance may be appraised (although not necessarily in the conscious sense). When judgements are not demanded, less learning to respond to the relationship will occur. They claim that "It can be predicted that when the limb is fully visible through an optical transforming system but no judgements of position are possible there will be no change from pre- to post-test judgements. It is difficult, however, to conceive of conditions in which complete control could be exercised over S's judgement of position."

This interpretation accounts for the influence of similarity between test and exposure phases of the experiment as the more similar situation will provide more information about the discrepancy, independently of other variables. Very similar exposure situations will provide sufficient information even with passive movement and the amount of information will be increased when the subject is forced to make spatial judgements. It can also explain the discrepant results of Held and associates as their measures were taken in a situation which differed considerably from the exposure situation, and in such circumstances the information provided by active movement could well exceed that by passive movement.

Studies which deal with the direction of movement also claim that the difference is due to increased information. Freedman, Hall and Rekoosh (1965) showed greater transfer and compensation with vertical hand motion than transverse hand motion and Lazar (1966) independently reached similar conclusions. Lazar discovered that the nature of the background is also important and that it is vertical movement against a vertical background that gives rise to greater adaptation than lateral movement against the same background. These effects were found when trial by trial measures of adaptation were examined but not when the DAE was examined; this raises questions about the usefulness of the DAE as a measure. Freedman et.al. attempted to explain their findings by the fact that vertical movement gives more cues and more rapid localization of the medial plane than does transverse motion. However, this interpretation does not fit Lazar's results and he hypothesized that it was due to the fact that subjects moving their hands vertically were on the target more of the time and thus obtained more information about the displacement.

Other studies are concerned with the nature of the learning that occurs, instead of the nature of the information provided. Harris (1965) and others mentioned above have claimed that all adaptation is due to proprioceptive changes and Rock, Mack, Adams and Hill (1965) report that this is true when the only evidence to spatial 'minification' is given by touch. In contrast Kalil and Freedman (1966[a]) hypothesize that adptation of the contralateral hand, which they found, is due to unperceived changes in eye position. In a second study (Kalil and Freedman, 1966[b]) they give evidence which supports this hypothesis; they found that after adaptation subjects displayed significant and persistent lateral occular rotation of which they were unaware. This explanation is not, however, consistent with the findings of Cohen (1966) in which such adaptation in the contralateral hand occurs only if the passive hand is visible to the subject during the period of adaptation with the active hand (Kalil and Freedman do not report whether the contralateral hand was visible in their experiment). However, Cohen does provide other evidence that adaptation is not solely due to proprioceptive changes. Complete transfer of the DAE was found from the exposed central area of the eye to the non exposed peripheral area, but when the peripheral area was exposed the DAE was largely confined to these areas.

These disparate results can be better understood in the light of a series of articles by McLaughlin and Rifkin (1965) and McLaughlin and Bower (1965[a] and 1965[b]) which showed that although adaptation to prism changes has the appearance of a unitary phenomenon, the intermediate stages of adaptation can be analysed into two components which combine additively. One of the two components, a change in the apparent position of the visual stimulus, transfers one hundred per cent to the unadapted hand, whereas the other, a change in the felt position of the adapted hand, does not transfer at all. McLaughlin and Bower (1965[b]) claim that it is possible that the latter adaption may also be due, at times, to a shift in the egocentric frame of reference during adaptation to the prism.

Similar claims come from an attempt by McFarland and Clarkson (1966) to relate the work on adaptation to body tilt to the work with adaptation to prisms. They suggest that body tilt and movement while wearing prisms both provide an atypical but constant relationship between vision and proprioception which leads to changes in the reference system defining the typical relation between visual stimulation and proprioceptive stimulation defining the body. This change may occur in both proprioception and vision. The changes reported in a particular study which emphasize one or the other, but not both, may be a function of the measuring task.

Hay and Pick (1966) examined the effect of long term optical displacement on a wide variety of sensory co-ordinates. The patterns of changes found indicates that a transient adaptation in the proprioceptive sense is succeeded by stable adaptation of the visual system. They discovered that increased information through greater movement and viewing the whole body, rather than a part of it, served to induce visual adaptation.

Thus evidence from work on adaptation to distorted vision indicates that movement is important in perceptual learning only because it provides additional information on the distorted relationship between vision and proprioception and that adaptation occurs in the less stable sense (proprioception) initially, but occurs in vision after further experience with, and information from, the environment. This suggests that movement may aid perceptual learning by providing information about the relationships between variables and that changes in relationships occur more readily in the less frequently used and less reliable senses. Before generalizing from such evidence, however, other evidence on the role of movement on perceptual learning, which is not dependent on distorted vision, should be examined.

Gyr, Brown, Willey and Zivian (1966) review much of the literature related to the role of movement in perception to demonstrate the need for any model of perception to regard the perceiver as active. They include; the more physiological theories of Von Holtz (1954) and Sperry (1958) which Held expanded in relation to his work,& experiments with animals in which movement is prevented or highly controlled. They include also the work by Gibson et.al. on the role of motor exploration in the establishment of constancies as well as the work with displaced vision. They conclude (p.184) that "it appears, at least for some animals, that perceptions of certain kinds may occur without accompanying voluntary motions, except, perhaps, eye motions. It also appears that, for some organisms at least, there are elaborate built in structures for some kinds of <u>elementary</u> form perceptions, but that these are insufficient in themselves to guarantee functional perceptual capabilities in the living animal which moves about and has to deal with motion-produced visual inputs. It is further suggested that the same kind of physical stimuli which are discriminated when movement is artificially excluded and made irrelevant are no longer discriminated when the animal looks at them while moving about if the animal has previously been deprived of patterned vision accompanied by voluntary motion." They thus claim that the difference between perception developed with or without movement in the environment lies in the dimensions of the environmental input which are abstracted by the system as invariant. As the invariants in visual input under active perception are those which hold under specific motor movements, they claim that efferent-afferent interaction becomes possible enabling the organism to define which features of the visual input will be attended to.

A review of Russian research into perceptual learning by Zaporoshets and Zinchenko (1966 p.404) claims that "the works of A.N. Leontyev, B.G. Ananyev, B.M. Teplov and others warrant the conclusion that the processes of sensation and perception like the other mental processes, do not develop isolatedly but in the context of different forms of the subject's activity, practical activity in the first place". A young child is unable to form an adequate perceptual image when visual and tactual stimulation alone are available but such images may be formed when practical stimulation with the object is available.

Summarizing all this evidence it would appear that movement is important in perceptual learning because it presents the subjects with information about the environment against which other possible perceptions are tested and, in some situations, provides different information than passive viewing. The nature of the movement and its importance to the subject are relevant and it is possible that some types of movement, particularly passive movement, may have little or no significance to the subject and hence not alter perception. Verbal judgements may alter perception more than movement, at times, as they alert the subjects to some aspects of the environment which may not be relevant to movement. Hence it can be hypothesized that when a subject is presented with a new perceptual instrument, learning will be more rapid if he is forced to make judgements about the environment which are based on the information from the aid. These judgements may be those demanded by movement about the environment or verbal judgements demanded by the experimenter to which verbal feedback is given. If Gyr et.al. are correct and movement leads to differences in the dimensions of the environmental input which are sbstracted as invariant, one would expect that individuals who move relative to the objects in the environment, as well as making judgements about it, will receive more information and will learn to use the aid in all situations more quickly than those that merely make judgements without movement, unless optimal information is already provided and the total information fills channel capacity.

Aims of this Thesis

The aims of this thesis can be divided into two groups:

1) Those which evaluate some aspect of the Kay Ultra device as an aid for the blind.

2) The use of the new perceptual system provided by the Kay Ultra Aid for the blind to test hypotheses stemming from theoretical claims about perception.

As little is known about either of these areas of research, it was thought that this should be an exploratory study which examines several variables and gives guidance for further more specific research rather than attempting any such research itself. The specific aims and hypotheses stemming from the above discussion are grouped under the two main areas of research below.

1. Those which evaluate some aspect of the Kay Ultra device as an aid for the blind.

   All previous studies attempting to evaluate the Aid have used the field study or obstacle course. The study of the psychophysics of the Aid and of differential training procedures have been ignored. This study attempts to partially fill this gap. As this area of research is essentially non theoretical, it is concerned with general aims and not specific hypotheses.

   These aims in detail are:-

   a) To examine the influence of a short period of training, and of movement within this period, on later performance with the Aid. This could help in the development of future training schedules.

   b) To obtain quantitative measures of the following aspects of size and distance perception using the Aid.

   i) Discrimination Thresholds

   ii) The extent to which estimates of size and distance remain constant when changes are made in the distance and/or texture, and size and/or texture, respectively, of the objects being judged.

c) To find how subjects interpret the skills involved in making size, distance and texture judgements using the Aid.

d) To determine the relationship of measures of auditory acuity and discrimination to measures of performance with the Aid.

e) To examine the relationship of personality variables, measured by The Eysenck Personality Inventory, to performance with the Aid.

2. The use of the new perceptual system provided by the Kay Ultra Aid for the blind to test hypotheses stemming from theoretical claims about perception.

a) Movement within the environment in addition to judgements about the same, during training, will provide extra information about the relationships between the output of the Aid and the environment and hence lead to better performance with the Aid (if optimal information has not already been provided by the verbal judgements without movement).

b) Movement within the environment during training will provide different information concerning the invariants of the output from the Aid and hence lead to greater constancy.

c) Background cues will provide additional information about the relationships within the stimulus context and thus lead to less uncertainty and greater constancy unless sufficient information is already available. This effect will be largest for the subject at a low level of perceptual development as the additional information is then needed more.

d) Constancy is related to the ease and confidence with which the judgements are made. The relationship between the confidence of constancy judgements and their departure from constancy is bipolar with a more rapid decrease in confidence associated with the departure from projective equality responses.

e) Judgements which are based on one dimension of the output of the Aid which is relatively independent of other aspects of the stimulus context will depart less from constancy than those judgements which are based on more than one dimension and are not independent of other aspects of the stimulus context.

f) Those stimulus changes which alter the output of the Aid in such a way that the dimensions on which judgements of another attribute are normally based are changed, will influence judgements of that attribute more than changes which alter only those dimensions of the Aid which are not normally involved in such a judgement.

g) When two such variables are altered at once, the effect will be additive.

Consequent Methodological Requirements

If these aims are to be realised, the experimental design must include training procedures that differ only in the amount of movement, relative to judged objects, that is experienced by the subjects. A control group having no training is needed to provide a baseline with which the differential training procedures can be compared. The experimental design must also provide measures of:

1) Skill after training.
2) Discrimination of size and distance when all other variables are equated. These measures should be taken at a minimum of three levels of each of the attributes.

3) Subjective equality of size and distance under controlled variations of the other variable and/or texture. (constancy judgements)

4) The influence of increased background cues on the constancy judgements.

5) The subjects ability to discriminate sounds, both before and after experience with the Aid. Measures on a control group must be obtained in order to determine whether any changes over this time stem from experience with the Aid.

6) Personality attributes.

7) Subjective ease of size, distance and texture judgements with the Aid.

8) Subjective descriptions of the cues used in judgements of the above attributes which are dependent on the Aid.

An experimental design which attempts to fulfil these requirements can be divided into three main areas:

1) Training sessions.

2) Experimental sessions.

3) Measures of individual differences.

The experimental sessions can be further divided into:

a) Discrimination sessions.

b) Constancy sessions.

CHAPTER 2

EXPERIMENTAL DESIGN AND PROCEDURE

General Experimental Design

As the experimental design included a moderately lengthy training period and individual differences were expected to be important, a factorial design with repeated measures on the same subject over most variables was used. Training was, of course, varied between subjects, as was the influence of additional background cues on constancy judgements. The latter variable was varied between subjects because there is a limit to the amount of time that any one individual can be expected to expend on any one experiment and this was one of the least important of the variables examined.

In an experimental design with repeated measures on the same subject there is a high possibility that order effect may contaminate the examined variables. Therefore, throughout this experiment, counter-balancing was employed to control any such effects. The measures of discrimination obtained were intended to indicate optimum ability in these skills, so measures of discrimination were taken both before and after the block of constancy trials. This would show whether learning was still occuring and, if it was, would provide a measure which more closely approminated that of optimum performance.

The general plan of the experiment is given in Table 1. Specific details are given later in the chapter.

TABLE 1

General Plan of Research

Number of Sessions	Experimental Groups		Control Group
1	Introduction and Seashore Measures of Musical Talents		Seashore Measures of Musical Talents
7	Training without movement	Training with movement	
16-20**	Experimental Sessions		
6-10	Discrimination Sessions		
4½-7	Constancy Sessions		
3-5½	Discrimination Judgements*		
1	Seashore Measures of Musical Talents and Eysenck Personality Inventory		Seashore Measures of Musical Talents

* At the end of the last discrimination session an audiometric test was administered to all experimental subjects and the questionnaires completed.

** The number of sessions varies because there were a set number of judgements to be made rather than a set number of hours to be spent on them.

Subjects

The experimental subjects were 24 volunteers (6 female and 18 male) from the undergraduate psychology classes of the University of Canterbury; 14 from the first year, 8 from the second and 2 from the third. The ages ranged from 17 - 39, with a mean of 21.28 years, at the start of the experiment. All had normal or corrected vision and were blindfolded for the purpose of the experiment.

Blindfolded sighted subjects were used because the following methodological considerations favour the use of such subjects and research, reviewed in chapter 1, has shown that measures obtained from them should not differ greatly from measures obtained from the blind.

1) There was less likelihood of positive or negative transfer from normal mobility or obstacle detection skills.

2) We can be more confident that the subjects' responses were based on information from the Aid because most sighted people need considerable experience before accurate unaided obstacle detection is possible.

3) It was more convenient; it would have been very difficult to obtain blind subjects at the times when the experimental room was available.

The control group for the measures on the Seashore Measures of Musical Talent consisted of 19 subjects from a first year psychology laboratory class.

Equipment

APPARATUS

As fine discrimination of size and distance was required, it was essential that some apparatus be constructed which enabled stimuli to be presented normally to the bean of the Aid, at a known distance and position with a constant angle of separation and with minimal interference from the supports of the stimuli and the surrounding environment. Changes in stimuli and distance must be able to be made rapidly, quietly and accurately. These needs were met by the construction of the apparatus shown in Appendix 2. The Aid was mounted on a Lipof camera tripod and movement restricted to that in a horizontal direction. The tripod was fitted to a wooden base from which two pairs of parallel 16ft. railway tracks projected at an angle of 45 degrees to each other with the pivot of the Aid at the point of intersection of two hypothetical lines drawn down the middle of each pair of tracks. A trolley ran smoothly and quietly within each set of tracks. A three inch pipe mounted vertically on each trolley supported a one inch diameter horizontal pipe projecting 8ft. forward towards the Aid. Stimuli were placed in the end of the pipe by means of a short length of one inch dowling attached at right angles to the back of each stimulus. The distance of the stimuli from the Aid was determined from the position of the trolley in relation to rulers attached to the railway lines. The subject was seated on a wheeled chair and pushed into place behind the Aid. A constant voltage of 8½ volts was provided by a transformer from the mains supply placed beneath the camera tripod. The whole equipment could be readily dismantled.

A hessian screen six feet high was suspended from four dexion stands connected by three lengths (6', 3' and 6' respectively) of dexion placed so that the screen was 10ft. from the subject at the point where it was slit to let the projecting poles of the main equipment pass through. This screen was used to provide some background information for some of the subjects, in the constancy sessions.

The above equipment could not be used for the training period due to delays in construction and so the stimuli were presented on 1/4 inch dowling stands 3 feet high for the 'no movement' group, who were seated, and 3 feet, 6 inches high for the 'movement' group, who were standing. The object was positioned by marks on the floor and the Aid was held in the hand. A normal 9 volt battery, attached to the Aid, provided the necessary power. As the judgements required at this stage were less precise, it was thought that this apparatus would be satisfactory.

Subjects were blindfolded by blacked out welders' goggles which excluded patterned light but allowed a little diffuse light to enter at the back edges. Throughout the experimental sessions a clicker was used to signal to the subjects when a judgement was required. This form of instruction was used in an attempt to decrease the possibility that experimenter expectation might bias the obtained results (Rosenthal 1966) by stereotyping communication. However, in any experiment which continues for many sessions some extra communication between subject and experimenter is inevitable and this may have lessened the advantages of the clicker.

STIMULI

The stimuli were circular throughout so that scanned width would be independent of the angle of scanning. All discs were cut out of 1/8 inch hardboard with the other textures attached to the front face when necessary. The stimuli for the training sessions were 4½", 7", 9", 14" and 18" diameter discs with hardboard, carpet (1/4 inch pile) and gravel (3/8") surfaces, presented at one foot intervals from 2 to 8 feet from the Aid. In the experimental sessions the variables were hardboard discs from 2½ to 20 inches diameter, increasing in quarter inch steps, and the standards were hardboard and carpet discs of 4½", 9" and 18" diameter. Distances ranged from 6 inches to 8 feet in quarter inch steps, with base distances of 3', 5' and 7'.

These stimulus values were used as they were considered to cover the middle ranges of sensitivity in the Aid, for size and distance, and to represent changes in both hardness and smoothness, the two main attributes of texture differences. The quarter inch interval in the experimental sessions was determined by preliminary experimentation without the appropriate apparatus again due to delays in manufacture. Allowances were made for the greater accuracy expected with the full equipment.

TESTS OF INDIVIDUAL DIFFERENCES

The auditory tests used were the Pitch, Loudness, Time and Timbre subtests of the Seashore Measures of Musical Talents (Seashore, Lewis and Saetveit 1960 revision) and the Amplivox Audiometer test.

The Pitch, Loudness and Time subtests of the Seashore were selected for administration as judgements of size and distance using the Aid are dependent on discrimination of these variables. The Timbre subtest was added at the second administration because the initial testing took less time than was expected and Timbre discrimination is related to texture perception, a variable of secondary importance in this study. The relatively low reliability coefficients of the tests reported by Seashore, Lewin and Saetveit (Pitch .84, Loudness .74, Time .71 and Timbre .68) make a control group a necessity. The Audiometer test was administered to obtain a measure of auditory acuity and check for specific frequency deafnesses.

The Eysenck Personality Inventory, Form B (Eysenck and Eysenck 1964) and an experimenter designed questionnaire (see Appendix 4) were administered to obtain both measures of personality attributes of the subjects and subject assessments concerning the use of the Aid, respectively.

Experimental Procedure

Each subject attended from 16 to 27 approximately half-hour sessions. As the only room large enough to eliminate echo from the walls was one that was used for psychology laboratory classes, experimentation could only be conducted when the room was not in use. This meant that only two sessions with each subject could be conducted each week. These two sessions were separated as equally as possible and 5/- a session paid to help reduce dropouts and absenteeism. There were no dropouts, but there were occasions when the subject did not appear at the appointed time. Because of the tight schedule this meant that the time between sessions was sometimes altered, but was never less than two days or more a week.

INTRODUCTION

The first session, which preceeded any training or experimentation, consisted of an introduction to the Aid and to the research programme, and the initial administration of the Seashore. The subjects were gathered in small groups in the room later used for experimentation, shown the aid and given the description as in Appendix 3. Before the first session using the Aid, the subjects were given additional instructions concerning the Aid, also shown in Appendix 3.

TRAINING

Two groups of eight subjects each were given training. The remaining 8 subjects being the 'no training' group who served as a control for the other two groups. The two training groups differed only in that one group was required to move relative to environment using the Aid while the other group was not permitted so to move. The training task for all these subjects was that of learning to recognise different sizes, distances and textures after initial familiarization with the stimuli. Verbal feedback was given to both groups after each judgement and one group moved out to the object after each judgement. The Aid was turned off between judgements to enable the stimuli to be changed.

It was desired that the subjects experience all combinations of size, distance and texture during the training period, but, as time was limited, each variable was judged under only three values of the other variables; variation in size and distance was limited to the three values which served as standards in the experimental sessions.

The resulting training program is presented in Table II. The subjects were blindfolded before entering the experimental room for each training session. The subjects not permitted movement were led to a seat by the experimenter and the subjects allowed movement were led to a mark on the floor where they stood and faced the object. This was done by getting the subject to

TABLE II

Training Programme

Session	Time		Activity	Stimuli
1	5 min		Introduction to the Aid	Aid
	10 min		Location of objects	9" hardboard disc at 5'
	15 min		Introduction to different distances and distance judgements	9" hardboard disc at all distances
2	5 min		Distance judgements	9" hardboard disc at all distances
	15 min		Introduction to different sizes and size judgements	All sizes of hardboard discs at 5'
	10 min		Introduction to different textures and texture judgements	9" discs of all textures at 5'
3	15 min		Size judgements	All sizes with
		5 min		carpet
		5 min		gravel
		5 min		hardboard surfaces at 7'
	15 min		Texture judgements	All textures on discs of
		5 min		18"
		5 min		9"
		5 min		4½" diameter discs at 3'
4	15 min		Distance judgements	18" diameter disc with
		5 min		gravel
		5 min		hardboard
		5 min		carpet surfaces at all distances
	15 min		Texture judgements	All textures on discs of
		5 min		9"
		5 min		18"
		5 min		4½" diameter discs at 7'
5	15 min		Distance judgements	4½" diameter discs with
		5 min		hardboard
		5 min		carpet
		5 min		gravel surfaces at all distances
	15 min		Size judgements	All size discs with
		5 min		carpet
		5 min		gravel
		5 min		hardboard surfaces at 3'
6	10 min		Size judgements	All size discs with
		5 min		gravel
		5 min		carpet surfaces at 5'
	10 min		Texture judgements	All textures on discs of
		5 min		18"
		5 min		4½" diameter at 5'
	10 min		Distance judgements	9" objects with
		5 min		carpet
		5 min		gravel surfaces at all distances
7	15 min		Judgements of one variable with all variables changing when told the values of the other variables	All combinations
		5 min	Texture judgements	
		5 min	Distance judgements	
		5 min	Size judgements	
	15 min		Judgements of one variable with all variables changing when not told the values of the other variables	All combinations
		5 min	Size judgements	
		5 min	Distance judgements	
		5 min	Texture judgements	

indicate when he detected an object which varied within a 90 degree arc 5ft. in front of him. The initial contact with each of the different attributes was done by the experimenter twice presenting each stimulus level to the subject (once in ascending and once in descending order) and informing the subject of its value before asking him to examine it. Throughout the rest of the training period the subjects were required to estimate the appropriate attribute of the stimulus presented and were then told the correct value. In the first six training sessions, successive judgements of each variable were made with only the judged variable changing. In the seventh session, the stimuli could change on all three variables between two judgements. No comparison judgements were provided during this training period as the aim was to give general training in perception of size, distance and texture and not skill in making comparison judgements.

Measures were taken only on the last two training sessions, as the interest was in the differential influence of training on later performance and not in the learning process during training.

EXPERIMENTAL SESSIONS

All 24 experimental subjects completed this part of the experiment designed to obtain measures of discrimination and constancy. The measures were obtained on the equipment described earlier, using the method of limits (with some modifications). The interval between successive stimuli was 1/4 inch in both size and distance except for distance discrimination judgements with the standard at 7 feet when it was 1/2 inch. This difference was introduced to examine the influences of the size of the interval on the measure of discrimination. Half of the series were of increasing magnitude (ascending) and half of decreasing magnitude (descending); half were made with the standard on the right and half with it on the left. No feedback was given to the subjects.

The method of limits was employed because it was considered to be the best available method of obtaining estimates of constancy and the same basic method had to be used in both parts of the experiment so that measures from the discrimination sessions could be used in the analysis of measures of constancy. The method of limits was seen as the best method for obtaining estimates of constancy because it was necessary to provide for a wide range of possible responses. The method of average error was not possible because a continuously increasing size stimulus, which did not change in texture, proved impossible to design. Further, the main response bias liable to occur with the method of limits (the tendency for the judged size to deviate in the direction of the physical size of the initial variable) can be corrected by averaging measures from ascending and descending trials, but the tendency of measures taken from the method of constant stimuli to concentrate about the center of the range cannot be controlled so easily. Finally, it was the most economical with time.

In the constancy sessions, subjects were not told the initial difference between stimuli and each series was stopped after an estimate of perceived equality was obtained. However, in the discrimination session the subjects were told the initial difference between stimuli and the series was continued through equality judgements to obtain both upper and lower thresholds of equality. This provision of information about the initial difference between stimuli ensures that the subject is faced with only two alternative responses at any one time and thus avoids violation of the requirements of the method of limits (Dember 1960). No time limit was placed on the subjects but they were instructed to make their judgements as quickly as possible. This led to considerable variation in the time taken and in some cases meant that all the observations with one standard could not be completed in one session. If it was necessary to take more than one session, the break was always made after half the judgements. All possible order effects within the discrimination series and constancy series were controlled by counterbalancing. The subjects within the training groups were randomly assigned to the different orders. Constancy judgements were assumed to be unrelated to the order of conditions within discrimination trials and so a new randomization was employed for this part of the experiment. Table 3 shows the resulting plan of research for all subjects.

Discrimination Sessions

Measures of discrimination were obtained both before and after the block of trials concerned with constancy to check whether learning had occured during this period. Distance discrimination judgements were made using 9 inch hardboard discs with standards of 3', 5' and 7' from the Aid and size discrimination judgements were made using 4½ inch, 9 inch and 18 inch diameter discs as standards 5' from the Aid. Twelve series of judgements were made at each level of both variables before the constancy trials and

TABLE III

PLAN OF EXPERIMENTAL SESSIONS

	No Training							
Subjects	1	2	3	4	5	6	7	8
Discrimination Sessions	S18	S4½	S4½	S18	D7	D3	D3	D7
	S9	S9	S9	S9	D5	D5	D5	D5
	S4½	S16	S18	S4½	D3	D7	D7	D3
	D7	D3	D7	D3	S18	S4½	S18	S4½
	D5	D5	D5	D5	S9	S9	S9	S9
	D3	D7	D3	D7	S4½	S18	S4½	S18
Background Cues	Yes	No	Yes	No	Yes	Yes	No	No
Constancy Sessions	S3c	S3c	S3h	D4½c	D4½h	D4½c	D4½h	S3h
	S7c	S7c	S7h	D18c	D18h	D18c	D18h	S7h
	S5c	S5c	S5c	D9c	D9c	D9c	D9c	S5c
	S7h	S7h	S7c	D18h	D18c	D18h	D18c	S7c
	S3h	S3h	S3c	D4½h	D4½c	D4½h	D4½c	S3c
	D4½c	D4½c	D4½h	S3c	S3h	S3c	S3h	D4½h
	D18c	D18c	D18h	S7c	S7h	S7c	S7h	D18h
	D9c	D9c	D9c	S5c	S5c	S5c	S5c	D9c
	D18h	D18h	D18c	S7h	S7c	S7h	S7c	D18c
	D4½h	D4½h	D4½c	S3h	S3c	S3h	S3c	D4½c
Discrimination Sessions	S18	S4½	D3	D7	S4½	S18	D3	D7
	S9	S9	D5	D5	S9	S9	D5	D5
	S4½	S18	D7	D3	S18	S4½	D7	D3
	D7	D3	S18	S4½	D3	D7	S18	S4½
	D5	D5	S9	S9	D5	D5	S9	S9
	D3	D7	S4½	S18	D7	D3	S4½	S18

	Training Without Movement							
Subjects	9	10	11	12	13	14	15	16
Discrimination Sessions	S18	S4½	S4½	S18	D7	D3	D3	D7
	S9	S9	S9	S9	D5	D5	D5	D5
	S4½	S18	S18	S4½	D3	D7	D7	D3
	D7	D3	D7	D3	S18	S4½	S18	S4½
	D5	D5	D5	D5	S9	S9	S9	S9
	D3	D7	D3	D7	S4½	S18	S4½	S18
Background Cues	No	Yes	No	No	Yes	No	Yes	Yes
Constancy Sessions	D4½c	D4½c	S3h	S3c	S3h	D4½h	S3c	D4½h
	D18c	D18c	S7h	S7c	S7h	D18h	S7c	D18h
	D9c	D9c	S5c	S5c	S5c	D9c	S5c	D9c
	D18h	D18h	S7c	S7h	S7c	D18c	S7h	D18c
	D4½h	D4½h	S3c	S3h	S3c	D4½c	S3h	D4½c
	S3c	S3c	D4½h	D4½c	D4½h	S3h	D4½c	S3c
	S7c	S7c	D18h	D18c	D18h	S7h	D18c	S7c
	S5c	S5c	D9c	D9c	D9c	S5c	D9c	S5c
	S7h	S7h	D18c	D18h	D18c	S7c	D18h	S7h
	S3h	S3h	D4½c	D4½h	D4½c	S3c	D4½h	S3h
Discrimination Sessions	D3	D7	S4½	S18	S4½	S18	D3	D7
	D5	D5	S9	S9	S9	S9	D5	D5
	D7	D3	S18	S4½	S18	S4½	D7	D3
	S4½	S18	D7	D3	D3	D7	S18	S4½
	S9	S9	D5	D5	D5	D5	S9	S9
	S18	S4½	D3	D7	D7	D3	S4½	S18

	Training With Movement							
Subjects	17	18	19	20	21	22	23	24
Discrimination Sessions	S18	S4½	S4½	S18	D7	D3	D3	D7
	S9	S9	S9	S9	D5	D5	D5	D5
	S4½	S18	S18	S4½	D3	D7	D7	D3
	D7	D3	D7	D3	S18	S4½	S18	S4½
	D5	D5	D5	D5	S9	S9	S9	S9
	D3	D7	D3	D7	S4½	S18	S4½	S18
Background Cues	No	No	No	No	Yes	Yes	Yes	Yes
Constancy Sessions	S3c	D4½c	S3h	D4½h	S3h	D4½h	D4½h	S3c
	S7c	D18c	S7h	D18h	S7h	D18h	D18c	S7c
	S5c	D9c	S5c	D9c	S5c	D9c	D9c	S5c
	S7h	D18h	S7c	D18c	S7c	D18c	D18h	S7h
	S3h	D4½h	S3c	D4½c	S3c	D4½c	D4½h	S3h
	D4½c	S3c	D4½h	S3h	D4½h	S3h	S3c	D4½c
	D18c	S7c	D18h	S7h	D18h	S7h	S7c	D18c
	D9c	S5c	D9c	S5c	D9c	S5c	S5c	D9c
	D18h	S7h	D18c	S7c	D18c	S7c	S7h	D18h
	D4½h	S3h	D4½c	S3c	D4½c	S3c	S3h	D4½h
Discrimination Sessions	S18	S4½	D3	D7	S4½	S18	D3	D7
	S9	S9	D5	D5	S9	S9	D5	D5
	S4½	S18	D7	D3	S18	S4½	D7	D3
	D7	D3	S18	S4½	D3	D7	S18	S4½
	D5	D5	S9	S9	D5	D5	S9	S9
	D3	D7	S4½	S18	D7	D3	S4½	S18

Discrimination Sessions: Both objects at 5' for Size judgements (S). Standard size diameter given in inches. Both objects 9" in diameter for distance judgements (D). Standard distance given in feet.

Constancy Sessions: Variable at 5' for size judgements. A 9" diameter hardboard standard was at entered distance (in feet). Variable 9" diameter for distance judgements. A hardboard standard of entered size (in inches) at 5'.

c - carpet

h - hardboard

eight after the constancy trials. Measurements were taken at three levels of each variable to enable an examination of the relationship between stimulus magnitude and discrimination threshold. Fewer trials were taken after constancy than before because variance was expected to be less and time was limited.

At the beginning of the first session subjects were led into the experimental room, seated at the apparatus, given the ear piece, shown how the Aid could be moved and given the following instructions.

"There are two objects in front of you. Turn the Aid until you have found both of them.....The one on your right is smaller (closer) than the one on your left. I will be increasing the size of the right hand disc (moving the right hand disc away from you) in small steps and I want you to tell me, each time I press the clicker, if it is still smaller (closer) than the object on your left or if it has become the same size (distance). You will not be told whether you are right or wrong. After you have made each judgement turn the Aid off so I can change the stimuli. Turn the Aid on again when you hear the clicker and make your next judgement. Try to keep the volume constant by turning the volume control approximately the same amount each time."

After the first equal judgement was given, the subject was instructed:

"Now I will keep increasing the size of the disc (moving the disc further away) and I want you to tell me whether the objects still sound equal or whether the one on the right now sounds larger (further away). Make a judgement each time the clicker is pressed. Do not worry if you have to say equal several times".

After two 'larger' (or 'further') judgements had been given, a descending series was introduced:

"Now I am starting with the object on the right larger (further away) from the Aid than the one on the left and decreasing the size of this object (bringing this object closer to you) in small steps. Tell me when the object on the right sounds larger (further), when it sounds equal and when it sounds smaller (closer)".

After two of the last judgements, the subjects were told that all future judgements would take this form and the experiment continued with no further instructions except those at the start of each series which informed the subject of the initial difference and the direction of change. The distance from equality of the initial stimulus for each series ranged from 3 to 8 steps and was randomly determined for each series.

The first two practice series were not recorded, but all other responses were recorded on the appropriate response sheet (see Appendix 5). A '+' was entered for a 'larger' or 'further' judgement, an '=' for a 'same' or 'equal' and a '-' for 'smaller' or 'closer' judgements.

Little introduction was given in later trials except when the variable being judged was changed. The subject was instructed that they would be using the same technique but that the objects were now equal in distance (size) and varying in size (distance). Two unrecorded practice trials were given. At the start of the second replication of discrimination judgements (after the constancy sessions) the subjects were told that they were to use the technique used at the start of the experiment; to determine whether one object <u>sounds</u> smaller (closer), then equal and finally larger (further away).

<u>Constancy Sessions</u>

In the constancy sessions size judgements were made comparing hardboard variables at 5' with 9" diameter hardboard standards at 3' and 7' and with 9" carpet standards at 3', 5' and 7'. Distance judgements were made comparinga9" diameter hardboard variable with

4½" and 18" diameter hardboard standards and 4½", 9" and 18" diameter carpet standards at 3'. Half the subjects made their judgements with minimal background cues, as was the case with all previous judgements, and half made their judgements with a constant background provided with the hessian screen. Four series of judgements were obtained from each subject under each condition.

A modified method of limits were used in which the subject was presented first with a variable which differed greatly from the standard in the appropriate direction, this difference being estimated to exceed a projective match. In contrast with the discrimination sessions the subject was not told the direction of the initial difference between objects, but told to judge the relationship himself, as it was thought that such instructions could contaminate the measures. If the appropriate response was made, the variable was moved towards the size of the standard in 1" steps for size and 6" steps for distance. When two equal judgements or contrasting judgements were made, the experimenter presented again the last variable evoking a difference judgement and approached equality in smaller steps

(1/4" for size and 1" for distance). The procedure being repeated a third time for distance, using 1/4" steps. If the first response was equal or in the opposite direction to that expected, the object was first moved away from equality till two appropriate responses were made and then the above method was applied. This modification was introduced to enable a wide range of stimuli to be covered.

The only indication the subjects were given that the situation had changed was the instruction that they would no longer be told what the initial difference between the two objects was but asked to determine this for themselves and the different procedure followed.

MEASURES OF INDIVIDUAL DIFFERENCES

After the introduction to the Aid in the first session the Seashore Measures of Musical Talents was administered to the subjects. Administration was in accordance with the 1960 manual. The test was re-administered 14 weeks later with the addition of the Timbre subtest. Not all experimental subjects had completed experimental work at this stage but this was the last date on which the first year psychology laboratory class, to which the Seashore had been administered as a control group, were meeting. The control group was tested in the same room as the experimental group.

The Eysenck Personality Inventory was administered at the same session as the second administration of the Seashore. The experimenter designed questionnaire was not given until the end of the last experimental session for each subject, as it was thought that earlier administration might have alerted the subject to alternative approaches to the signals from the Aid and hence altered responses. The Audiometric test was also administered at the end of the last experimental session for each subject. The subject was seated at least three feet away from the battery operated Audiometer, facing in the opposite direction and wearing the earphones. Measures were restricted to the ear on which the earphone of the Aid was worn throughout the experiment (the right ear for all but three of the subjects who admitted to hearing defects in this ear). The subject was given the clicker used in the experiments and told to press it each time he heard a noise through the earphone. The method of limits was used with the time interval between stimuli being varied randomly. One ascending and one descending trial was conducted at all the frequency levels after one practice trial (for both ascending and descending series) at 1000cps.

CHAPTER 3

RESULTS

The sets of measures obtained from each of the areas of research described in the last chapter are presented in the same order. The interrelations between different measures from each area of research and their relationship with measures previously presented are reported after the analysis of each set of measures.

Measures from Training Sessions

As the emphasis of this experiment was on the influence of the differential training procedures on later performance, measures were confined to the two final sessions. Measures were taken on both these sessions because there was a change in procedure in the final (seventh) session.

The measure of performance for size and distance judgements was the number of intervals (i.e., stimuli or possible responses) between the response given and the stimulus size. As it cannot be claimed that there were equal intervals between the different textures provided, such a method was not appropriate for such judgements and so the number of correct responses was taken as the measure of performance. Similar measures were obtained for size and distance judgements and these were correlated (using r) with the above measures of average error to determine whether the different measures were related. The resulting coefficients were .49 and .95 for size and distance respectively in the sixth training session and .79 and .97 in the seventh training session. As these correlations were obtained from measures from 16 subjects there are 14 degrees of freedom, and so, with the exception of size judgements in the sixth training, all are significant beyond the .01 level. This indicates that the two measures are concerned with much the same aspects of performance; the method of average error is probably the most sensitive.

In the sixth training session two judgements at each stimulus level of size and distance were made by each subject, with objects of two different textures, (gravel and carpet) hence each cell entry in the analyses of variances, presented in tables 4 and 5, was the sum of two errors. Three judgements were made of stimuli of each texture with objects of two different sizes (4½" and 18" diameter) and the cell entries in the analysis of variance on this data (table 6) were the number of these judgements made correctly.

TABLE 4

Analysis of Variance of Error in Size Recognition in the Sixth Training Session

Source	SS	df	MS	F
Between Subjects	15.692	15		
Training	2.755	1	2.775	$2.982_{(1, 14)}$
Subjects within groups	12.937	14	.924	
Within Subjects	269.300	144		
Size (of Stimuli)	27.023	4	6.756	$3.817_{(4, 56)}$**
Training X Size	4.652	4	1.163	<1
Size X Subjects within groups	99.125	56	1.770	
Texture (of Stimuli)	.505	1	.505	<1
Training X Texture	.057	1	.057	<1
Texture X Subjects within groups	19.938	14	1.424	
Size X Texture	26.902	4	6.727	$4.760_{(4, 56)}$**
Training X Size X Texture	11.970	4	2.993	$2.118_{(4, 56)}$
Size X Texture X Subjects within groups	79.128	56	1.413	

** $p < .01$

GRAPH 1: SIZE JUDGEMENTS AT THE END OF TRAINING AS A FUNCTION OF THE SIZE AND TEXTURE OF THE OBJECT.

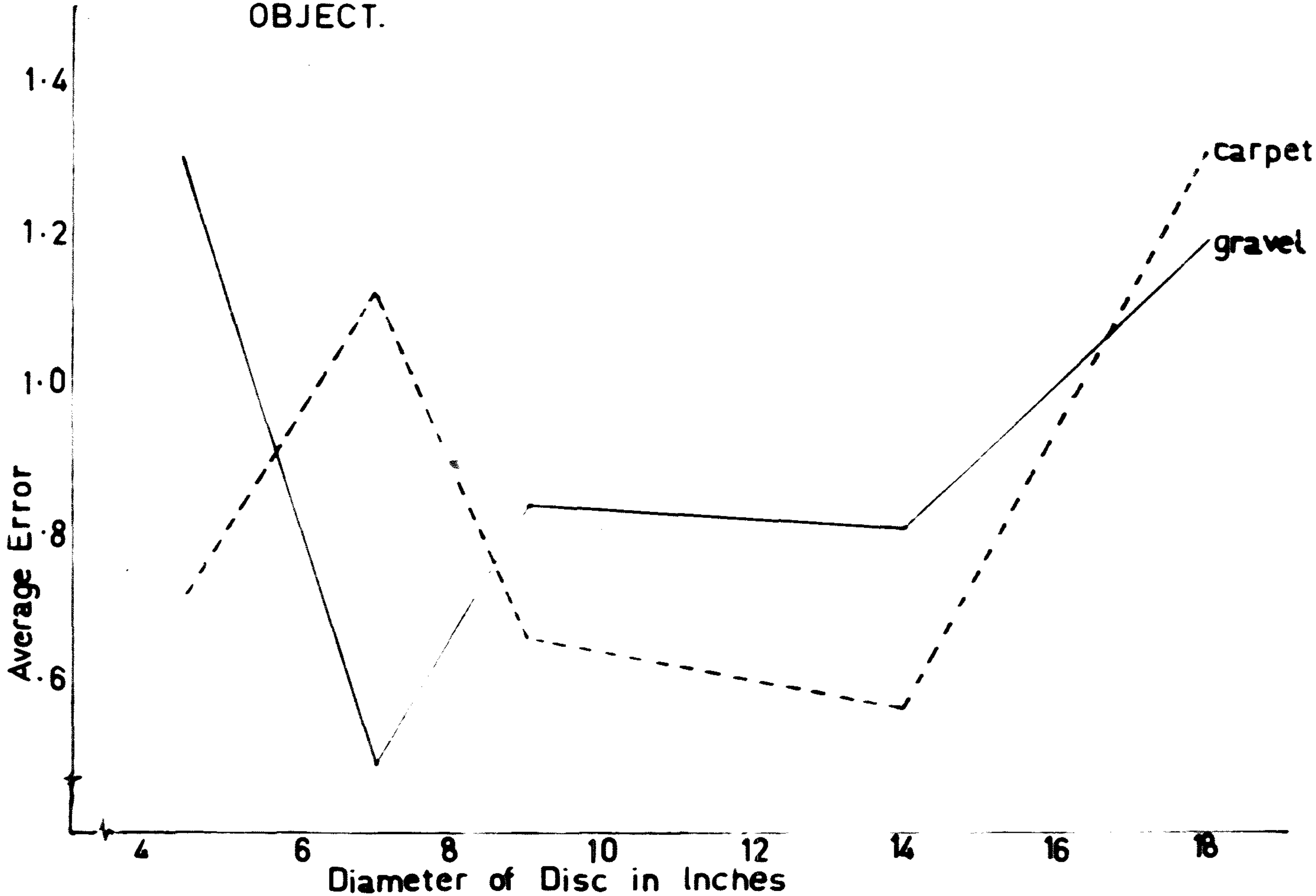


TABLE 5

Analysis of Variance of Error in Distance Recognition in the Sixth Training Session

Source	SS	df	MS	F
<u>Between Subjects</u>	<u>57.071</u>	<u>15</u>		
Training	7.142	1	7.142	$2.003_{(1,14)}$
Subjects within groups	49.929	14	3.566	
<u>Within Subjects</u>	<u>271.143</u>	<u>208</u>		
Distance (of Stimuli)	25.714	6	4.286	$3.309_{(6,84)}^{**}$
Training X Distance	8.608	6	1.435	$1.108_{(6,84)}$
Distance X Subjects within groups	108.821	84	1.295	
Texture (of Stimuli)	.642	1	.642	< 1
Training X Texture	.317	1	.317	< 1
Texture X Subjects within Groups	22.184	14	1.584	
Distance X Texture	9.858	6	1.643	$1.541_{(6,84)}$
Training X Distance X Texture	5.433	6	.905	< 1
Distance X Texture X Subjects within groups	89.566	84	1.066	

** $p < .01$

GRAPH 2 : DISTANCE JUDGEMENTS AT THE END OF TRAINING AS A FUNCTION OF DISTANCE

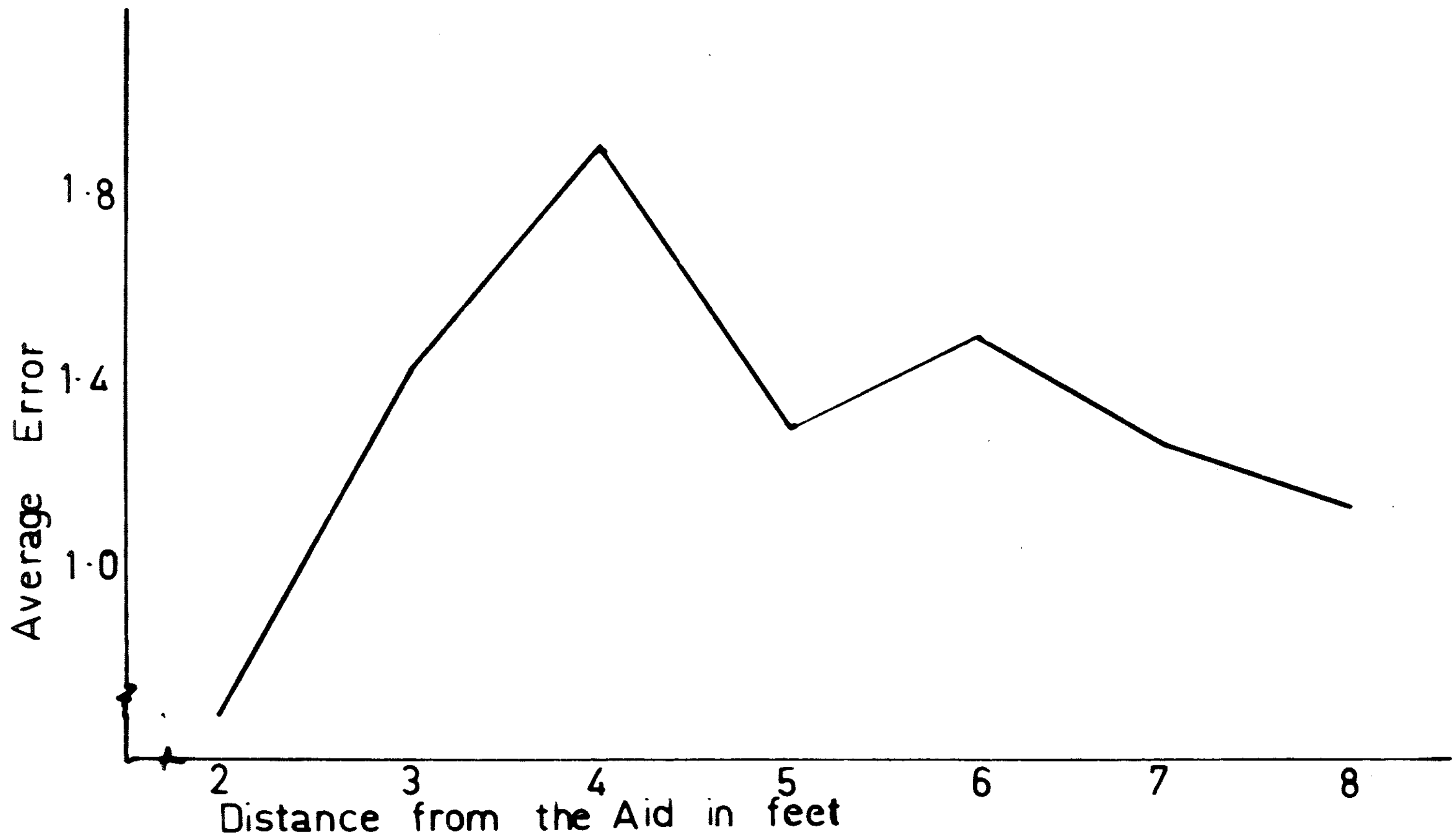


TABLE 6

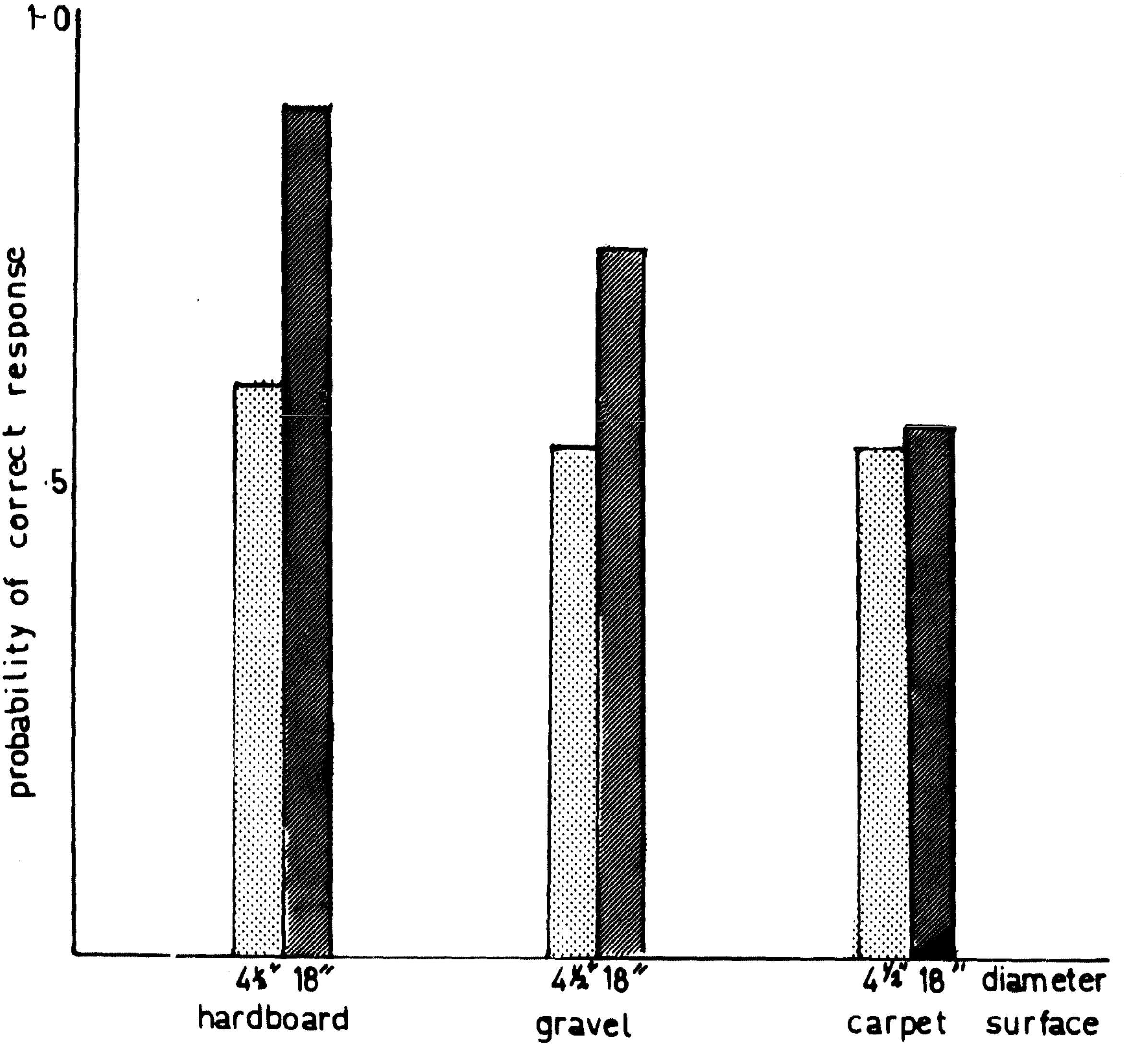
Analysis of Variance of Correct Texture Recognitions in the Sixth Training Session

Source	SS	df	MS	F
Between Subjects	17.906	15		
Training	3.011	1	3.011	$2.830_{(1,14)}$
Subjects within groups	14.895	14	1.064	
Within Subjects	64.834	80		
Texture (of Stimuli)	5.646	2	2.823	$3.830_{(2,28)}$*
Training X Texture	.145	2	.072	< 1
Texture X Subjects within groups	20.543	28	.737	
Size (of Stimuli)	6.511	1	6.511	$10.123_{(1,14)}$**
Training X Size	.093	1	.093	< 1
Size X Subjects within groups	8.996	14	.643	
Texture X Size	2.770	2	1.385	$2.048_{(2,28)}$
Training X Texture X Size	1.189	2	.594	< 1
Texture X Size X Subjects within groups	18.941	28	.676	

** $p < .01$

* $.05 < p < .01$

GRAPH 3: TEXTURE JUDGEMENTS AT THE END OF TRAINING AS A FUNCTION OF THE SIZE AND TEXTURE OF THE OBJECT.



In the seventh training session all three variables could be changed at once. As a maximum of two judgements were made at each stimulus size and distance analysis of the position of the stimulus in the series was not possible. Nor was it possible to study the instructional variable because it was confounded with order effects. Hence a one way analysis of variance was used for both these judgements; the resulting summary tables can be seen in tables 7 and 8. As more texture judgements were made with each object surface, due to the smaller number of stimuli used, a two way analysis of variance was conducted on this data; the surface of the objects was analysed as well as differential training. (table 9)

Differential training was shown to significantly effect distance judgements in the final session, when all three variables could change between judgements; those subjects who moved relative to the stimuli during training showed the greatest amount of error.

The position of the stimulus in the stimulus series affected performance in the sixth training session alone: the stimuli at the end of the series were judged most accurately when distance was judged and least accurately when size was judged. Texture differences cannot be

TABLE 7

Analysis of Variance of Error in Size Recognition in the Seventh Training Session

Source	SS	df	MS	F
Training	49.000	1	49.000	$1.442_{(1, 14)}$
Error	476.750	14	33.982	
Total	525.750	15		

TABLE 8

Analysis of Variance of Error in Distance Recognition in the Seventh Training Session

Source	SS	df	MS	F
Training	196	1	196	$10.554_{(1, 14)}^{**}$
Error	260	14	18.571	
Total	456	15		

** $p < .01$

TABLE 9

Analysis of Variance of Correct Texture Recognition in the Seventh Training Session

Source	SS	df	MS	F
<u>Between Subjects</u>	<u>24.666</u>	<u>15</u>		
Training	.333	1	.333	<1
Subjects within groups	24.333	14	1.738	
<u>Within Subjects</u>	<u>41.333</u>	<u>32</u>		
Texture (of stimuli)	2.000	2	1.000	<1
Training X Texture	1.166	2	.583	<1
Texture X Subjects within groups	38.166	28	1.363	

ordered so easily but the nature of the surface was significantly related to correct recognition, in the same training session; the hardboard surface was correctly identified most frequently and the carpet surface least frequently. This change of performance with change in texture was not, however, significant in the seventh training session. It is possible that the effect of stimulus position on the accuracy on size and distance judgements would also have disappeared in this situation as one would expect that such a position effect, which is probably based on anchoring, to demand perception of the complete stimulus range.

The difference in the character of the position effect for size and distance suggests that the extreme stimuli act as anchors for distance judgements as they are easily discriminable, but that there is a tendency towards central judgements when size is judged, due to the absence of any clear indication of the extremes. The hardboard surface gives the loudest and purest note and this could account for the easier recognition. Carpet is probably mistaken most frequently because the note produced by this surface is intermediate in purity of tone, between hardboard and gravel. This suggests that it is the purity of the note and not the volume which is the major cue for texture judgements. If loudness was the major cue, gravel would have been the most difficult to judge as the loudness evoked by this surface is intermediate to that evoked by the other surfaces.

The texture of the stimulus as a main effect was not significant in the size and distance analyses of the sixth training session but interacted significantly with the position of the size stimulus in the appropriate stimulus series. Fewer errors were made with the smallest object when it had a carpet surface, but judgements of a gravel object showed central tendency with objects at both ends of the stimulus series showing the most error. The carpet surface gives a softer note than the gravel surface and this could bias the judgements towards the smaller objects. The size of the stimulus affected the accuracy with which texture judgements were made. The larger object was judged more accurately, presumably because more information was provided.

Interrelationship of Measures

Intercorrelations between measures of the different judgements within and between the two training sessions are presented in table 10. The only significant coefficients were those between the same measures in the

TABLE 10

Intercorrelation of Measures Taken at the End of Training

n = 16 d.f. = 14

	Variable Judged	6th Training Session			7th Training Session		
		Size	Distance	Texture	Size	Distance	Texture
6th training session	Size	-	.31	.40	.68**	.30	.61
	Distance		-	.38	.05	.59**	.21
	Texture			-	.29	.31	.47
7th training session	Size				-	.13	.17
	Distance					-	.34
	Texture						-

** $p < .01$

two sessions indicating that the same skill was demanded in both sessions. The direction of the other coefficients, with the exception of the relation of size and distance judgements when all variables can change at once, though not significant, indicate a tendency for skill in judging one attribute to be associated with skill in judging the other. This suggests that there is a general factor due to skill in handling the Aid.

Measures from Discrimination Sessions

The data obtained from the discrimination sessions were coded so that the number 10 represented the value (point) between the stimulus magnitude below equality and equality itself and an increment of 1 a change of a quarter of an inch. This meant that each stimulus step was represented by an increment of one for all series except distance judgements with the standard at 7', when there was an increase of 2 with each stimulus step. The thresholds were taken as the point at which judgements changed from the initial judgement to two successive equal or final judgements and the point at which it changed from the initial or equal judgement to two successive final judgements. Measures of discrimination were obtained by finding the difference between the upper and lower thresholds. This value is a coded score equal to two just noticible differences (j.n.d.'s).

The first analysis on discrimination data was performed on data obtained from an additional session in which size was judged with a 9 inch diameter standard, administered at the end of the first set of discrimination measures. This session was conducted to determine whether a slight error in the apparatus influenced size judgements. The correction or otherwise of this error, which meant that when the objects were marked as being equally distant from the Aid one was 1/4 of an inch further away than the other, did not significantly influence subjective equality or discrimination of size.

RESPONSE STRATEGIES

The analysis on points of subjective equality (p.s.e.) from the above session also examined the order of presentation of stimuli (ascending or descending) and the position of the standard (on the right or on the left). These variables were included to check assumptions basic to the method of limits (Guilford 1954). The resulting 2 X 2 X 2 analysis of variance, with repeated observation on the last two measures, is summarized in table 11. The cell entries were the mean of three upper and three lower thresholds for each subject.

TABLE 11

Analysis of Variance of the Subjective Equality of Size Judgements with Corrected and Uncorrected Apparatus

Source	SS	df	MS	F
Between Subjects	43.127	23		
Apparatus (corrected-not corrected)	.064	1	.064	<1
Subjects within groups	43.063	22	19.574	
Within Subjects	302.500	72		
Position (of Standard)	.048	1	.048	<1
Apparatus X Position	2.409	1	2.409	<1
Position X Subjects within groups	57.654	22	2.621	
Order (of Stimuli)	157.928	1	157.928	$53.228_{(1,22)}^{**}$
Apparatus X Order	.349	1	.349	<1
Order X Subjects within groups	65.275	22	2.967	
Position X Order	.086	1	.086	<1
Apparatus X Position X Order	.807	1	.807	<1
Position X Order X Subjects within groups	17.944	22	.816	

** $p < .01$

The position of the standard had no significant effect on the measures of subjective equality, but order of stimulus presentation did. This difference is important as the method of limits depends on the subjects faithfully reporting their experience and this suggests that they are not so doing. Some allowance must be made for this in analysing the data from the main experiment.

The direction of the difference (table 13) and inspection of the data suggests that while the first change in a series of judgements is determined mainly by the stimuli the second is largely determined by a responses strategy in which the probability of a change in response is a function of the number of equal judgements already made. The ascending series gives rise to a p.s.e. smaller than equality and the descending series one that is larger than equality. Inspection of the data shows that while the first change of judgement is on the appropriate side of equality and is reasonably consistent, the second change is variable and may be on the wrong side of objective equality. The large number of equal judgements demanded for size judgements may have highlighted this tendency which was possibly motivated by the fear, expressed by some subjects, that failure to discriminate would be taken as personal failure.

The apparatus error could be easily corrected for distance judgements and so no extra session was demanded for this purpose. The variable of order of stimulus presentation was examined, instead, in a one way analysis of variance, with repeated observations, on estimates of the point of subjective equality from the before constancy distance judgements with the standard at 5 feet (table 12). Each cell entry represents the mean of 6 upper and 6 lower threshold measures. The significant F ratio and an examination of the deviations from objective equality (table 13) shows that distance judgements are subject to the same responses bias as size judgements but to a lesser amount.

In an attempt to allow for and examine this response bias, analysis of data from the discrimination sessions of the main experiment is conducted, both on measures obtained by taking the difference of the average of allupper thresholds and of all lower thresholds, i.e. 12 before constancy and eight after constancy, (from complete data) and on measures obtained by only using upper thresholds from descending series and lower thresholds from descending series (from emended data). This halves the number of measures used in the determination of each

TABLE 12

Analysis of Variance of Subjective Equality of Distance for Ascending and Descending Series with Standard at 5'

Source	SS	df	MS	F
Between Subjects	11.694	23		
Within Subjects	69.025	24		
Order	20.237	1	20.237	$9.541_{(1,23)}$**
Residual	48.788	23	2.121	
Total	80.719	47		

** p .01

TABLE 13

The Difference Between Subjective and Objective Equality for Ascending and Descending Series Expressed in Inches

	Ascending	Descending
For size judgements in extra session standard of 9"	-.313	.327
For distance judgements with standard at 5' measured before constancy	-.163	.162

One interval in the method of limits was 1/4"

The - sign is used to represent deviation in the smaller or closer direction.

measure of discrimination. It should be noted that when the discrimination measure is taken from the complete data, it is a measure of the number of equal judgements made by the subject and is thus very sensitive to any response strategy used. A measure of response bias was determined separately for the upper and lower thresholds by differencing the mean of the thresholds obtained from ascending and descending series.

Measures of response bias were correlated with measures of discrimination taken from complete and emended data because the difference between size and distance measures of response bias, the claim that it is based on expectation of the number of judgements required and the suggestion that it is due to the fear, in some subjects, of personal failure leads to the hypothesis that the response bias will be greater when the task is found to be more difficult. The correlations were calculated, over 24 subjects, for size and distance judgements (tables 14 and 15) at each standard magnitude before and after constancy. The resulting coefficients for upper and lower thresholds were averaged for each series (Guilford 1965) giving 44 degrees of freedom. Care must be taken in interpreting these coefficients as the 5% level of significance is dubious when a large

TABLE 14

Correlations of Measures of Discrimination and Response Bias for Size Judgements

Measure			j.n.d. from Complete data						j.n.d. from emended data					
	Replication		Before constancy			After constancy			Before constancy			After constancy		
		Diameter of std. in ins.	4½	9	18	4½	9	18	4½	9	18	4½	9	18
Response Bias	Before Constancy	4½	-.26	-.06	.03	-.28	-.23	-.10	.68**	.25	.14	-.13	-.22	.07
		9	-.35*	-.25	-.11	-.09	-.23	-.10	-.06	.63**	.34*	-.08	.09	-.03
		18	.03	.10	-.35*	-.34*	-.03	-.34*	.17	.05	.79**	.24	.07	.32*
	After Constancy	4½	-.12	-.20	-.33*	-.09	-.22	.04	-.04	.12	.07	.25	-.22	-.07
		9	-.01	-.10	-.14	-.06	-.33*	.03	.09	.18	.24	.15	.56**	.43**
		18	.08	-.27	.09	-.14	-.19	-.07	.26	.25	.32*	.08	.26	.55**

* $.05 < p < .01$

** $p < .01$

TABLE 15

Correlations of Measures of Discrimination and Response Bias

for Distance Judgements

Measure			j.n.d. from Complete data						j.n.d. from Emended data					
	Replication		Before Constancy			After Constancy			Before Constancy			After Constancy		
		Distance of std. in feet.	3	5	7	3	5	7	3	5	7	3	5	7
Response Bias	Before Constancy	3	.05	-.21	-.10	.19	.10	.13	.37**	.23	.11	.14	.06	.06
		5	.14	-.06	.17	.35*	.45**	.17	.48**	.64**	.63**	.35*	.32*	.12
		7	-.20	.55**	-.13	.18	.09	.16	.22	.25	.71**	.22	.03	.05
	After Constancy	3	.07	-.24	-.20	-.26	-.16	-.24	-.04	.09	-.03	.35*	-.05	-.25
		5	.25	.14	.25	.21	.11	.27	.30*	.07	-.06	.21	.66**	.59**
		7	.20	.18	.19	.30	.21	.28	.04	-.05	-.00	.24	.19	.11

* .05 < p < .01

** p < .01

number of correlations, such as these, are examined.

Measures of response bias were directly associated with the discrimination measures from the emended data from the same series. This was not true for discrimination measures from the complete data. This indicates that the response bias was associated with difficulty of discrimination and was not the major determinant of the discrimination measure from the complete data.

THE MAIN EXPERIMENT

The discrimination data obtained from the two replications of the discrimination sessions were examined in 3 X 2 X 2 X 3 X 2 analyses of variance, with repeated measures on the last two variables. The variables examined were; the nature of training, the order in which size and distance were judged, reversal of order in the second replication, magnitude of standard and replications. The reversal of the order of the series in the second replication of the experiment for half the subjects was included to aid interpretation of any change that might be found between replications. Separate analyses were conducted for size and distance judgements using measures from complete and emended data. Tables 16 - 19 summarize the analyses and graphs 4 - 13 demonstrate the significant ratios. Ratios which are significant in the analysis of measures from the emended data are probably largely due to changes in response strategy and not to changes in discrimination.

Analyses of Measures of Size Discrimination

The size of the standard is significantly related to fineness of discrimination in both analysis of size judgements with the largest object giving the biggest discrimination threshold. This is the only significant ratio common to both analyses.

One other main effect is significant in the analysis on measures from the complete data, that of replication; discrimination measures were smaller when judgements were made after constancy than before. This change could be due to discrimination learning or to increased response bias. The non significance of this ratio in the analysis on emended data suggests that the latter is the correct interpretation.

The only significant interaction in the analysis of measures from the emended data was that of Size of standard X Order of presentation; discrimination was finer when size judgements were made prior to distance judgements of the 4½" and 18" diameter standards but not for the 9 inch diameter standard. Controlling for order effects by counterbalancing meant that the 9" standard was never judged first or last and this may be

TABLE 16

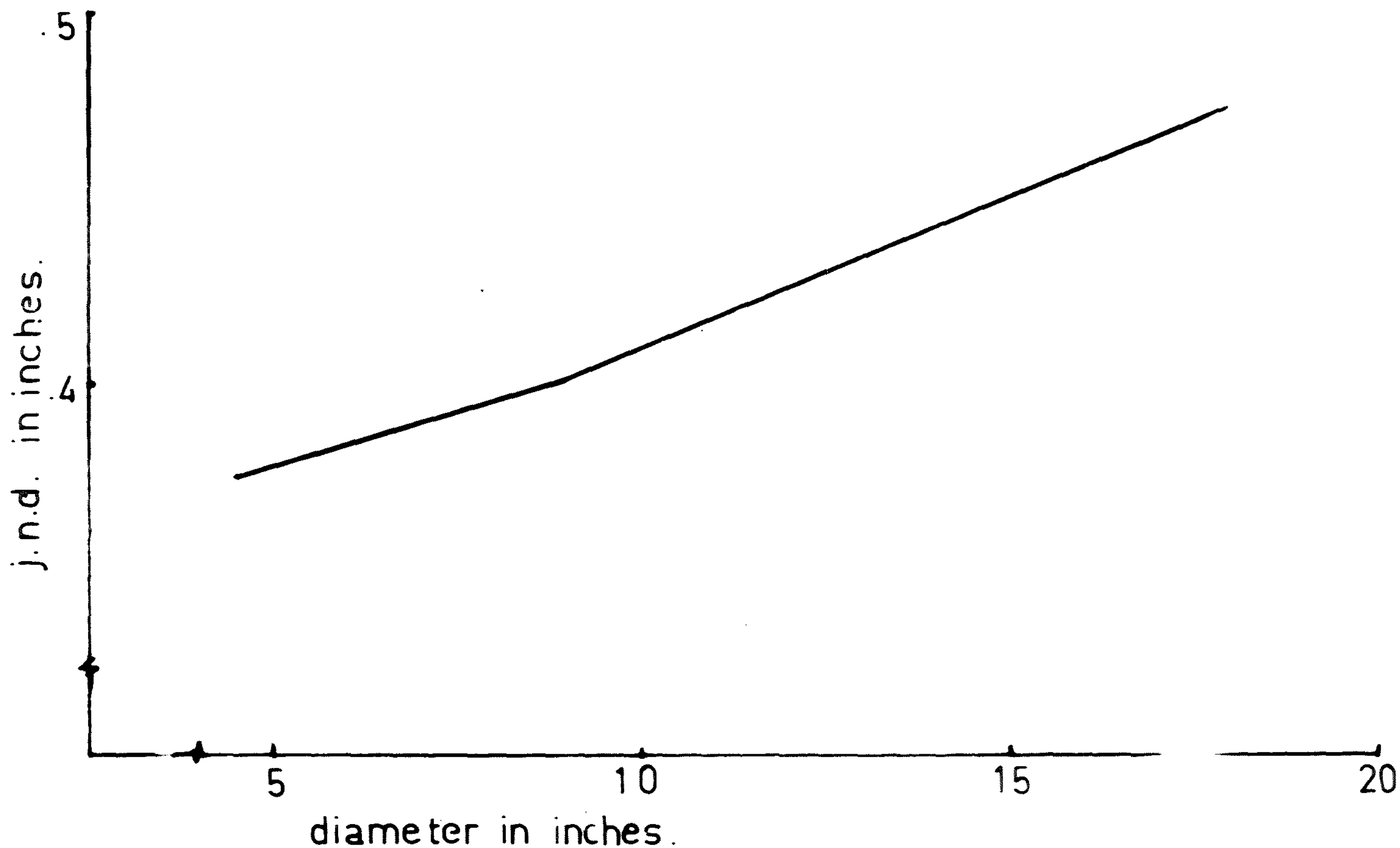
Analysis of Variance on Size Discrimination
Measures from Complete data

Source	SS	df	MS	F
<u>Between Subjects</u>	<u>123.883</u>	<u>23</u>		
Training	9.589	2	4.795	<1
Order	.116	1	.116	<1
Reversal (of order after Constancy)	9.209	1	9.209	$1.414_{(1,12)}$
Training X Order	1.320	2	.660	<1
Training X Reversal	7.518	2	3.759	<1
Order X Reversal	17.827	1	17.827	$2.738_{(1,12)}$
Training X Order X Reversal	.172	2	.086	<1
Subjects within groups	78.132	12	6.511	
<u>Within Subjects</u>	<u>157.893</u>	<u>120</u>		
Size (of Standard)	16.141	2	8.071	$14.775_{(2,24)}^{**}$
Training X Size	1.985	4	.496	<1
Order X Size	1.627	2	814	$1.489_{(2,24)}$
Reversal X Size	.247	2	.123	<1
Training X Order X Size	2.338	4	.581	$1.070_{(4,24)}$
Training X Reversal X Size	4.953	4	1.238	$2.267_{(4,24)}$
Order X Reversal X Size	.334	2	.167	<1
Training X Order X Reversal X Size	16.239	4	4.060	$7.432_{(4,24)}^{**}$
Size X Subjects within groups	13.109	24	.546	
Replication (Before or after Constancy)	19.265	1	19.265	$20.595_{(1,12)}^{**}$
Training X Replication	7.564	2	3.782	$4.432_{(2,12)}^{*}$
Order X Replication	.066	1	.066	<1
Reversal X Replication	4.908	1	4.908	$5.247_{(1,12)}^{*}$
Training X Order X Replication	11.156	2	5.578	$5.936_{(2,12)}^{*}$
Training X Reversal X Replication	1.320	2	.660	<1
Order X Reversal X Replication	4.634	1	4.634	$4.954_{(1,12)}^{*}$
Training X Order X Reversal X Replication	2.414	2	1.207	$1.290_{(2,12)}$
Replication X Subjects within groups	11.225	12	.935	
Size X Replication	1.346	2	.673	<1
Training X Size X Replication	1.828	4	.457	<1
Order X Size X Replication	.126	2	.063	<1
Reversal X Size X Replication	.151	2	.076	<1
Training X Order X Size X Replication	2.559	4	.639	<1
Training X Reversal X Size X Replication	5.323	4	1.330	$1.231_{(4,24)}$
Order X Reversal X Size X Replication	.380	2	.190	<1
Training X Order X Reversal X Size X Replication	.709	4	.177	<1
Size X Replication X Subjects within groups	25.946	24	1.081	

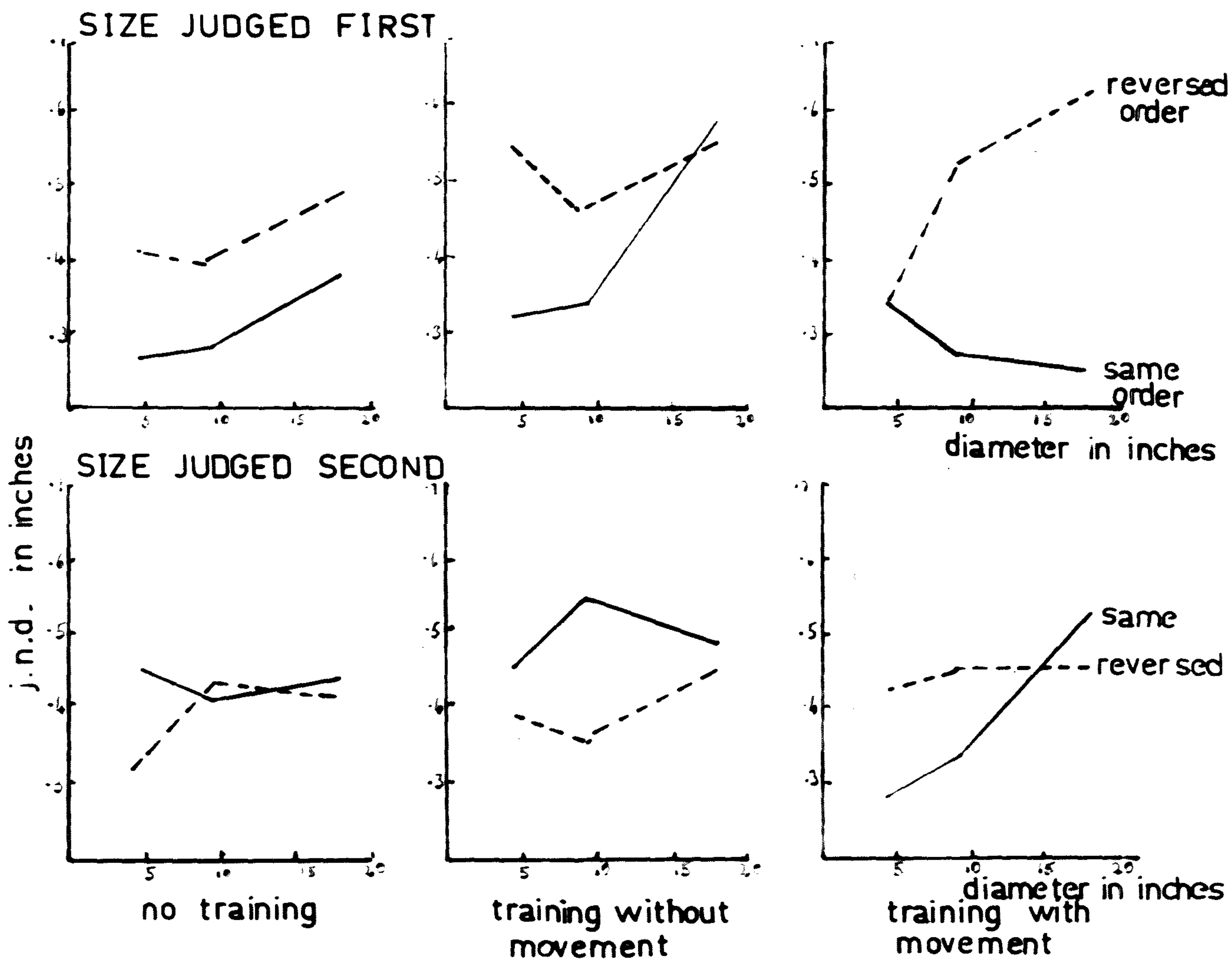
** $p < .01$

* $.05 < p < .01$

GRAPH 4: SIZE DISCRIMINATION MEASURES, FROM THE COMPLETE DATA, AS A FUNCTION OF STIMULUS MAGNITUDE.



GRAPH 5: SIZE DISCRIMINATION MEASURES FROM THE COMPLETE DATA.
TRAINING X ORDER X REVERSAL X SIZE



GRAPH 6: SIZE DISCRIMINATION MEASURES FROM THE COMPLETE DATA.
TRAINING X ORDER X REVERSAL X REPLICATION

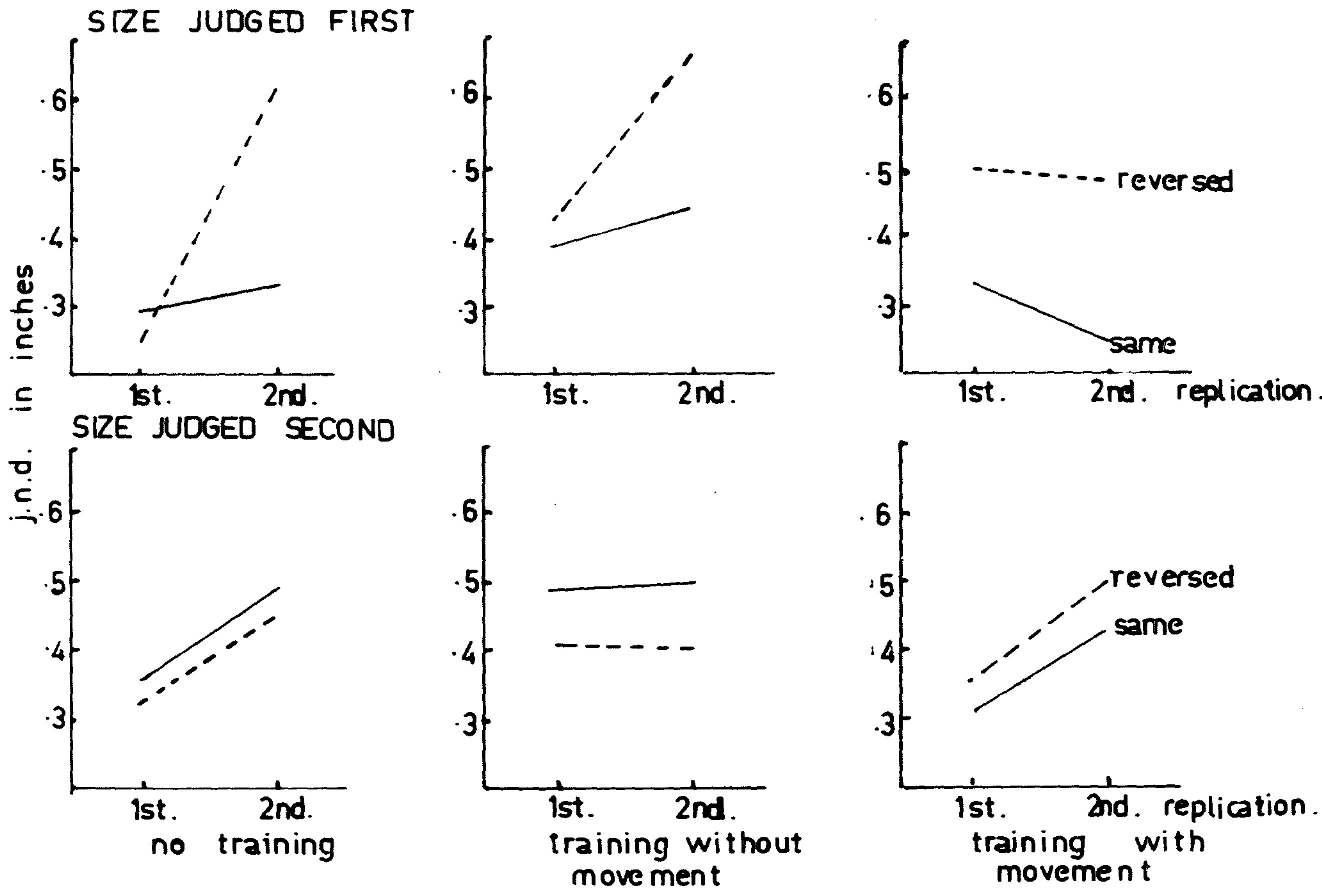


TABLE 17

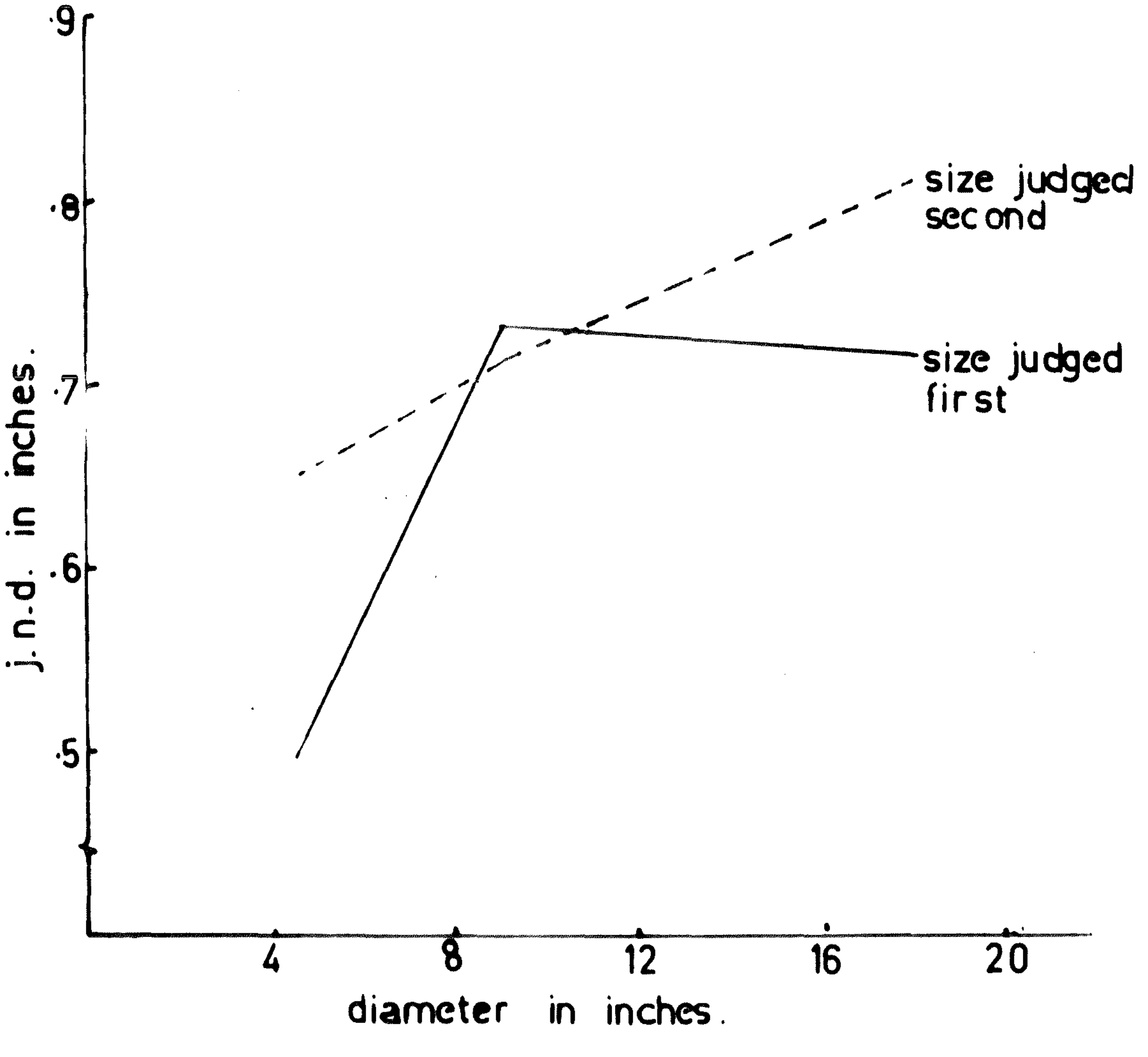
Analysis of Variance on Size Discrimination
Measures from Emended data

Source	SS	df	MS	F
<u>Between Subjects</u>	<u>188,774</u>	<u>23</u>		
Training	.697	2	.349	< 1
Order	13,143	1	13,149	$1,179_{(1,12)}$
Reversal (of order after Constancy)	7,411	1	7,411	< 1
Training X Order	2,041	2	1,021	< 1
Training X Reversal	.441	2	.221	< 1
Order X Reversal	29,794	1	29,794	$2,673_{(1,12)}$
Training X Order X Reversal	1,520	2	.760	< 1
Subjects within groups	133,727	12	11,144	
<u>Within Subjects</u>	<u>361,096</u>	<u>120</u>		
Size (of Standard)	61,237	2	30,667	$16,596_{(2,24)}$**
Training X Size	10,656	4	2,664	$1,442_{(4,24)}$
Order X Size	11,959	2	5,979	$3,235_{(2,24)}$*
Reversal X Size	.861	2	.431	< 1
Training X Order X Size	10,309	4	2,577	$1,394_{(4,24)}$
Training X Reversal X Size	9,616	4	2,404	$1,301_{(4,24)}$
Order X Reversal X Size	11,496	2	5,748	$3,110_{(2,24)}$
Training X Order X Reversal X Size	22,262	4	5,557	$3,007_{(4,24)}$
Size X Subjects within groups	44,350	24	1,848	
Replication (before or after Constancy)	10,206	1	10,206	$3,562_{(1,12)}$
Training X Replication	1,216	2	.608	< 1
Order X Replication	.628	1	.628	< 1
Reversal X Replication	12,057	1	12,057	$4,208_{(1,12)}$
Training X Order X Replication	3,017	2	1,509	< 1
Training X Reversal X Replication	5,197	2	2,599	< 1
Order X Reversal X Replication	2,114	1	2,114	< 1
Training X Reversal X Order X Replication	13,027	2	6,514	$2,274_{(2,12)}$
Replication X Subjects within groups	34,384	12	2,865	
Size X Replication	1,061	2	.531	< 1
Training X Size X Replication	8,750	4	2,188	$1,055_{(4,24)}$
Order X Size X Replication	4,119	2	2,059	$1,016_{(2,24)}$
Reversal X Size X Replication	2,263	2	1,132	< 1
Training X Order X Size X Replication	3,821	4	.955	< 1
Training X Reversal X Size X Replication	6,281	4	1,570	< 1
Order X Reversal X Size X Replication	8,903	2	4,452	$2,196_{(2,24)}$
Training X Order X Reversal X Size X Replication	12,655	4	3,164	$1,561_{(4,24)}$
Size X Replication X Subjects within groups	48,651	24	2,027	

** $p < .01$

* $.05 < p < .01$

GRAPH 7 : SIZE DISCRIMINATION MEASURES, FROM THE EMENDED DATA, AS A FUNCTION OF ORDER AND SIZE.



the reason for this exception. The direction of the change is, however, difficult to explain except by postulating that the first judgement was made with more care.

In contrast the analysis on measures from the complete data shows all the following interactions to be significant: Training X Order X Reversal X Size, Training X Replication, Reversal X Replication, Training X Order X Replication and Order X Reversal X Replication. All but one of these interactions includes replication as one of the variables and that one includes all the other variables. Examination of the relevant data indicates that the change over replications is not dependent on the constancy sessions as the biggest change occurs when there was maximal separation of the two sets of size judgements and the smallest change when size was judged second each time. It would thus appear that the difference arises within each replication of discrimination judgements with those subjects judging distance first giving the smallest measures and those judging size first the largest. As this interaction is significant only in the analysis of measures from complete data, an interpretation which is dependent on response bias will be most satisfactory. Instruction was issued at the start of each replication that the subjects were to judge according to experience. This would emphasize objective judging and the time since this reminder together with the experience of more easily made distance judgements between instruction and judgements, may have led to increased response bias in the second half of each set of discrimination sessions.

Training is also a recurring variable in the interactions in this analysis and, as can be seen from the graphs, the "no training" group have the smallest discrimination measures before constancy but not after constancy. The order in which size and distance judgements were made has the opposite effect on the two "trained" groups of subjects which reverses after constancy sessions. These interactions are probably due to transfer from the training sessions leading to different response strategies; a more detailed explanation is not thought necessary.

Analysis of Measures of Distance Discrimination

The analysis of measures of distance discrimination from the complete data (table 18) and from the emended data (table 19) do not differ as greatly as the analyses of size measurements. This was expected as it was noted

TABLE 18

Analysis of Variance on Distance Discrimination

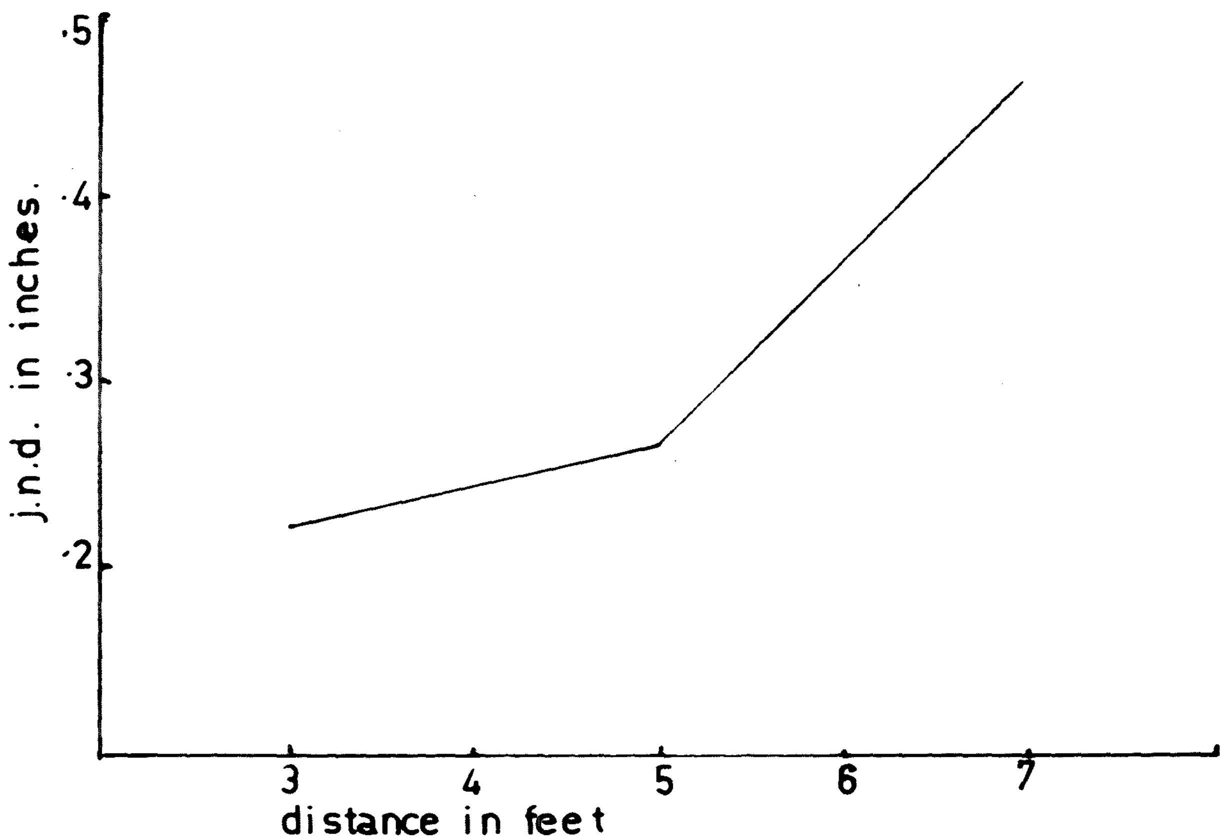
Measures from the Complete Data

Source	SS	df	MS	F
<u>Between Subjects</u>	<u>165,031</u>	<u>23</u>		
Training	21,665	2	10,833	$1,417_{(2,12)}$
Order	1,893	1	1,893	<1
Reversal (of order after Constancy)	2,344	1	2,334	<1
Training X Order	20,422	2	10,211	$1,336_{(2,12)}$
Training X Reversal	8,745	2	4,373	<1
Order X Reversal	.075	1	.075	<1
Training X Order X Reversal	18,141	2	9,071	$1,186_{(2,12)}$
Subjects within groups	91,744	12	7,645	
<u>Within Subjects</u>	<u>209,563</u>	<u>120</u>		
Distance (of Standard)	90,649	2	45,328	$31,266_{(2,24)}$**
Training X Distance	.893	4	.223	<1
Order X Distance	.027	2	.013	<1
Reversal X Distance	2,713	2	1,356	<1
Training X Order X Distance	4,040	2	1,010	<1
Training X Reversal X Distance	6,669	4	1,667	$1,150_{(4,24)}$
Order X Reversal X Distance	.421	2	.210	<1
Training X Order X Reversal X Distance	3,011	4	.753	<1
Distance X Subjects within groups	34,792	24	1,450	
Replication (before or after Constancy)	1,008	1	1,008	<1
Training X Replication	1,978	2	.989	<1
Order X Replication	2,136	1	2,136	$1,440_{(2,12)}$
Reversal X Replication	.013	1	.013	<1
Training X Order X Replication	.479	2	.239	<1
Training X Reversal X Replication	10,560	2	5,280	$3,559_{(2,12)}$
Order X Reversal X Replication	.235	1	.235	<1
Training X Order X Reversal X Distance	.025	2	.013	<1
Replication X Subjects within groups	17,803	12	1,484	
Distance X Replication	2,738	2	1,396	$1,878_{(2,24)}$
Training X Distance X Replication	.659	4	.165	<1
Order X Distance X Replication	.709	2	.355	<1
Reversal X Distance X Replication	.167	2	.084	<1
Training X Order X Distance X Replication	.527	4	.132	<1
Training X Reversal X Distance X Replication	2,547	4	.637	<1
Order X Reversal X Distance X Replication	6,448	2	3,224	$4,423_{(2,24)}$*
Training X Order X Reversal X Distance X Replication	.821	4	.205	<1
Distance X Replication X Subjects within groups	17,495	24	.729	

** $p \leq .01$

* $.05 \leq p \leq .01$

GRAPH 8 : DISTANCE DISCRIMINATION MEASURES, FROM THE COMPLETE DATA, AS A FUNCTION OF DISTANCE.



GRAPH 9: DISTANCE DISCRIMINATION MEASURES FROM THE COMPLETE DATA. ORDER X REVERSAL X DISTANCE X REPLICATION.

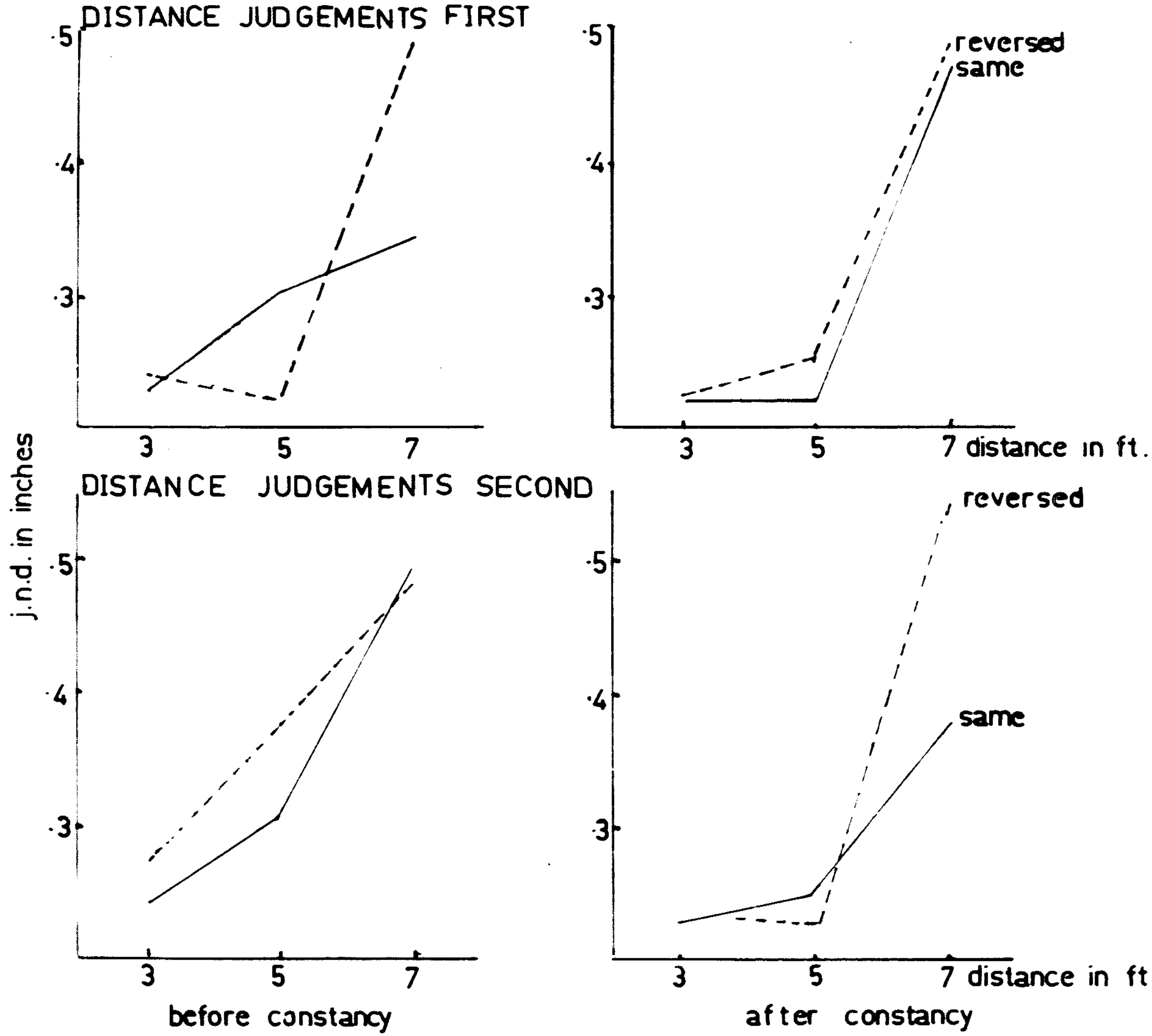


TABLE 19

Analysis of Variance on Distance Discrimination

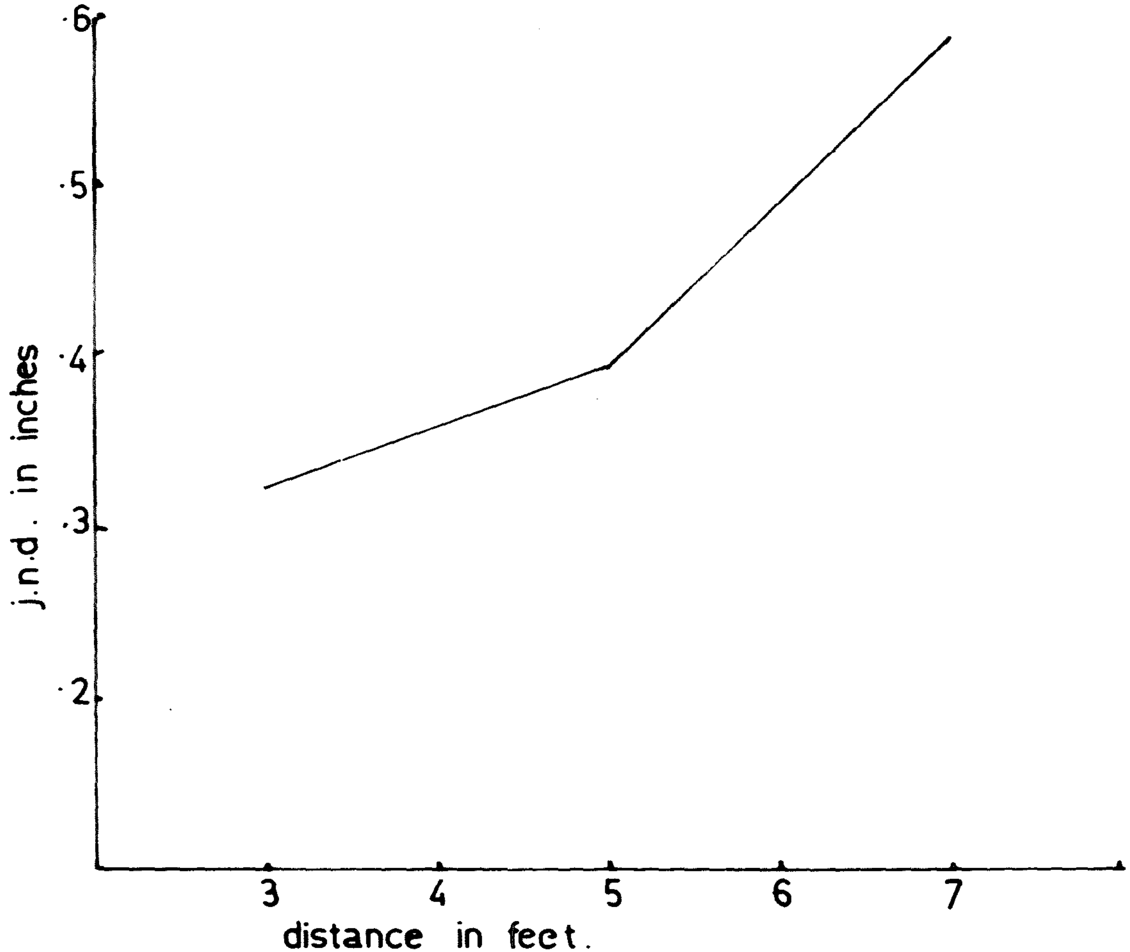
Measures from Emended Data

Source	SS	df	MS	F
Between Subjects	393.874	23		
Training	11.348	2	5.674	<1
Order	1.723	1	1.723	<1
Reversal (of order after Constancy)	2.991	1	2.991	<1
Training X Order	6.308	2	3.154	<1
Training X Reversal	55.910	2	27.955	$1.255_{(2, 12)}$
Order X Reversal	30.785	1	30.785	$1.382_{(1, 12)}$
Training X Order X Reversal	17.549	2	8.774	<1
Subjects within groups	267.260	12	22.272	
Within Subjects	601.391	120		
Distance (of Standard)	128.858	2	64.428	$14.862_{(2, 24)}$**
Training X Distance	7.784	4	1.946	<1
Order X Distance	2.457	2	1.228	<1
Reversal X Distance	.401	2	.201	<1
Training X Order X Distance	3.388	4	.847	<1
Training X Reversal X Distance	27.827	4	6.957	$1.605_{(4, 24)}$
Order X Reversal X Distance	8.560	2	4.280	<1
Training X Order X Reversal X Distance	6.033	4	1.508	<1
Distance X Subjects within groups	104.033	24	4.335	
Replication (before or after Constancy)	18.123	1	18.123	$3.193_{(1, 12)}$
Training X Replication	8.432	2	4.216	<1
Order X Replication	38.289	1	38.289	$6.746_{(1, 12)}$*
Reversal X Replication	2.574	1	2.574	<1
Training X Order X Replication	2.610	2	1.305	<1
Training X Reversal X Replication	3.383	2	1.692	<1
Order X Reversal X Replication	2.800	1	2.800	<1
Training X Order X Reversal X Replication	3.438	2	1.719	<1
Replication X Subjects within groups	68.117	12	5.676	
Distance X Replication	17.651	2	8.825	$2.901_{(2, 24)}$
Training X Distance X Replication	5.079	4	1.269	<1
Order X Distance X Replication	28.298	2	14.149	$4.651_{(2, 24)}$*
Reversal X Distance X Replication	.572	2	.286	<1
Training X Order X Distance X Replication	12.059	4	3.015	<1
Training X Reversal X Distance X Replication	6.619	4	1.655	<1
Order X Reversal X Distance X Replication	6.577	2	3.289	$1.081_{(2, 24)}$
Training X Order X Reversal X Distance X Replication	14.424	4	3.606	$1.185_{(4, 24)}$
Distance X Replication X Subjects within groups	73.005	24	3.042	

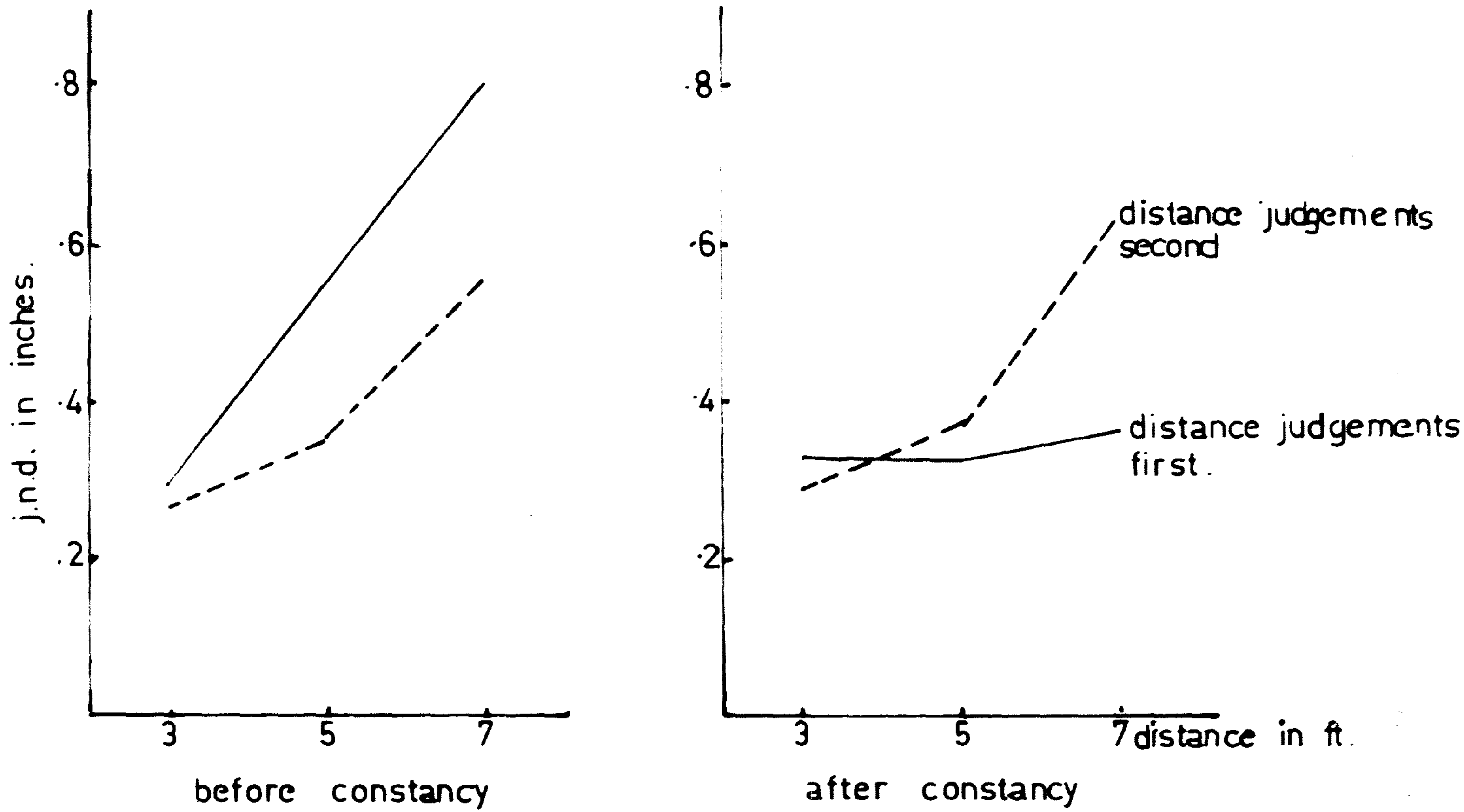
** $p < .01$

* $.05 < p < .01$

GRAPH 10: DISTANCE DISCRIMINATION MEASURES, FROM THE EMENDED DATA, AS A FUNCTION OF DISTANCE



GRAPH 11 : DISTANCE DISCRIMINATION MEASURES FROM THE EMENDED DATA. ORDER X DISTANCE X REPLICATION.



above that distance judgements exhibit less response bias. In both analyses the only significant main effect is the distance of the standard from the subject; discrimination becoming finer as the distance between the Aid and the Object decreases.

The significant interactions are, however, completely different in the two analyses. Analyses of measures from the complete data has only one significant interaction which is the 4 way interaction of Order X Reversal X Distance X Replication. Any psychological interpretation of such an interaction is uncertain and there is no attempt to do so as the interaction probably stems from response bias. The analysis of the emended data has two significant interactions; the two way interaction of Order X Replication and the three way interaction which adds distance to the two variables being considered. Subjects who made distance judgements first gave considerably smaller discrimination measures in the second replication than the first, while those who made size judgements first gave much the same measure on the two occasions. This effect becomes more noticeable with the increasing distance of the objects from the subject. Thus improvement over time has occurred with greater improvement at the greater distances. Lack of any significant interaction with reversal in the second replication suggests that most of this improvement occurred within the first replication, and was probably due to initial adaptation to the apparatus and method; the more difficult judgements showing the most improvement.

Summary

To summarize these analyses: Training had a significant effect on discrimination measures only when they were taken from the complete data and were therefore sensitive to any response bias. Change over replications as a main effect and in interaction with other variables was significant mainly when the measures analysed came from the complete data and thus may also be ascribed to response bias. Two interactions with replication were, however, found in the analysis of measures from the emended distance data and are probably best interpreted as being due to the need for adaptation to the experimental design. The analysis of measures from the emended size data shows one significant interaction, Size X Order, which suggests that the very first size judgement was made more finely. This is difficult to explain.

Discrimination and the Magnitude of the Standard

The magnitude of the standard has a significant effect in all analyses; the discrimination interval increasing with increase in magnitude of the variable. Table 20 shows the average j.n.d. at each level. This increase was predicted and, as the analysis of variance is not a directional test, this hypothesis was further examined by using the non-paramentric, one-tailed L test. The discrimination measurements for each stimulus magnitude were ranked for each subject; measures differing by less than .1 were considered to be equal and ranked accordingly. L was determined for measures taken before constancy, after constancy and the sum of the two, using measures from the complete and emended data, for both size and distance. The results (Table 21) shows that the directional hypothesis is supported in all these situations.

The more restricted hypothesis of the modified form of Weber's Law, first suggested by Helmholtz 1859, was also examined. This claims that the relationship of stimulus magnitude to fineness of discrimination is linear, i.e., that

$$\Delta I = kI + b$$

where ΔI is a measure of discrimination, usually the j.n.d.

I is the magnitude of the standard

k is a constant giving the slope of the line

and b is another constant giving the intercept on the I axis.

TABLE 20

Just Noticible Differences (j.n.d.) in Inches at Differing Magnitudes of Size and Distance

Size Discrimination
(Object at 5')

Diameter of Object	4.5"	9"	18"
From complete data	.375	.401	.474
From emended data	.576	.726	.765

Distance Discrimination
(Object at 9")

Distance from Subject	3'	5'	7'
From complete	.238	.269	.462
From emended data	.303	.396	.587

TABLE 21

L Tests of the Directional Hypothesis that the Just Noticiable Difference Increases with Increasing Stimulus Size

Source			L
<u>Size Discrimination</u>			
	Complete Data	Before Constancy	306.5**
		After Constancy	303.5*
		All Observations	301.5*
	Emended Data	Before Constancy	305.5**
		After Constancy	309.5*
		All Observations	314.0**
<u>Distance Discrimination</u>			
	Complete Data	Before Constancy	321.0**
		After Constancy	318.5**
		All Observations	324.0**
	Emended Data	Before Constancy	315.5**
		After Constancy	303.5*
		All Observations	310.0**

L crit for $p < .01$ = 304.128**

$105 < p < .01$ = 299.376*

TABLE 22

Analysis of Trend of Size Discrimination from Emended Data with Stimuli of Increasing Size

Source	SS		MS	F
Between Subjects	377.518	23		
Within Subjects	365.681	48		
Size of Stimuli	122.474	2	61.237	$11.583_{(2,46)}^{**}$
Residual	243.207	46	5.287	
Total	743.199	71		
Test for Trend				
Linear Trend	93.140	1	93.140	$16.061_{(1,47)}^{**}$
Deviation from Linear	272.541	47	5.799	

** $p < .01$

$\Delta I = 0.025I + .554$ when the radius was the measure of magnitude

$= 0.0007I + .554$ when the area was the measure of magnitude

TABLE 23

Analysis of Trend of Distance Discrimination From Emended Data with Stimuli at Increasing Distances

Source	SS	df	MS	F
Between Subjects	787.749	23		
Within Subjects	578.679	48		
Distance of Stimuli	257.714	2	128.875	$18.466_{(2,46)}^{**}$
Residual	320.965	46		
Total	1366.427	71		
Tests for Trends				
Linear Trend	247.908	1	247.908	$35.229_{(1,47)}^{**}$
Deviations from Linear	330.771	47	7.037	

** $p < .01$

$\Delta I = 0061 + .073$

This constant is usually negative and taken as the threshold constant. Weber claimed that this constant was zero.

The above hypothesis was tested by subjecting the measures from the emended data to a test for linear trends (Winer 1962 p. 132). The measures from the complete data were not examined as they were not believed to give an uncontanimated measure of discrimination. As there were no significant interactions between replication and magnitude of the standard, the data was reduced to a one way analysis of variance, with repeated measures, for the trend analysis. The resulting analyses can be found in tables 22 and 23.

Neither size nor distance departs significantly from linearity; the resulting constants obtained in each case are presented at the end of the above tables. The linear trend predicted 96% of the variance associated with the magnitude of the stimulus for distance judgements and 76% for size. Distance departs less from linearity and more closely approaches the traditional form of Weber's law which claims that b is equal to zero.

Interrelationships within Measures from Discrimination Sessions

The intercorrelations between measures of size and of distance discrimination can be seen in tables 24 and 25

TABLE 24

Intercorrelations of Measures of Size Discrimination

$n = 24, \quad d.f. = 22$

Measure			j.n.d. from complete data						j.n.d. from emended data					
	Replication		Before Constancy			After Constancy			Before Constancy			After Constancy		
		Diameter of Std. in ins.	4½	9	18	4½	9	18	4½	9	18	4½	9	18
j.n.d. from complete data	Before Constancy	4½	-											
		9	.58**											
		18	.30	.50*										
	After Constancy	4½	.57**	.22	-.05									
		9	.51*	.45*	.39	.72**								
		18	.40	.45*	.15	.52**	.52**							
j.n.d. from emended data	Before Constancy	4½	.34	.33	.13	.06	.07	.14						
		9	-.27	.32	.22	-.18	-.09	.01	.09					
		18	.17	.23	.16	.34	.19	.47*	.23	.34				
	After Constancy	4½	.26	.30	-.18	.34	.36	.32	.09	.14	.19			
		9	.40	.33	.23	.51*	.53**	.48*	.14	.21	.32	.41*		
		18	.20	.52**	.23	.06	.13	.61**	.30	-.27	.52**	.26	.56**	-

* $.05 < p < .01$

** $p < .01$

TABLE 25

Intercorrelations of Measures of Distance Discrimination

n = 24 d.f. = 22

Measure			j.n.d. from complete data						j.n.d. from emended data					
	Replication		Before Constancy			After Constancy			Before Constancy			After Constancy		
		Distance of std. in feet.	3	5	7	3	5	7	3	5	7	3	5	7
j.n.d. from complete data	Before Constancy	3	-											
		5	.72**											
		7	.69**	.48*										
	After Constancy	3	.67**	.45*	.57**									
		5	.64**	.47*	.48*	.84**								
		7	.66**	.40	.55**	.82**	.70**							
j.n.d. from emended data	Before Constancy	3	.60**	.10	.63**	.55**	.52**	.62**						
		5	.58**	.26	.57**	.53**	.59**	.57**	.78**					
		7	.27	-.14	.44*	.45*	.43*	.45*	.57**	.58**				
	After Constancy	3	.45*	.19	.33	.58**	.66**	.50*	.35	.42*	.41*			
		5	.53**	.29	.47*	.72**	.75**	.66**	.56**	.42*	.27	.57**		
		7	.33	.06	.45*	.43*	.34	.56**	.62**	.27	.32	.22	.69**	-

* .05 p .01

** p .01

TABLE 26

Correlations of Measures of Size and Distance Discrimination

n = 24   d.f. = 22

Measure			j.n.d. from Complete Size Data					
	Replication		Before Constancy			After Constancy		
		Magnitude of Std.	4½	9	18	4½	9	18
j.n.d. from complete distance data	Before Constancy	3	.34	.08	.12	.29	.14	-.04
		5	.39	-.03	.18	.48*	.34	.32
		7	.46*	.12	.23	.26	.14	.08
	After Constancy	3	.11	-.16	-.30	.33	-.12	-.03
		5	.11	-.05	-.25	.21	-.18	.15
		7	.19	-.11	-.18	.44*	.08	-.05

Diameter in ins.

Measure			j.n.d. from Emended Size Data					
	Replication		Before Constancy			After Constancy		
		Magnitude of Std.	4½	9	18	4½	9	18
j.n.d. from emended distance data	Before Constancy	3	.08	-.12	.11	-.19	-.06	-.19
		5	.28	-.09	.19	-.19	-.08	-.13
		7	.32	-.31	-.15	-.30	-.44*	-.29
	After Constancy	3	.21	-.12	.26	-.10	.13	.31
		5	-.26	-.17	.04	.01	.16	.09
		7	-.28	.00	-.06	-.02	.02	-.14

Diameter in ins.

Distance in feet

* .05 p .01

TABLE 27

Correlations of Measures of Performance during Training to Measures of Discrimination

d.f. = 42

Measures		Size j.n.d.		Distance j.n.d.	
		Before Constancy	After Constancy	Before Constancy	After Constancy
Sixth	Size Judgements	.03	.27	-.10	.07
Training	Distance Judgements	.02	.08	.18	.10
Session	Texture Judgements	-.16	.31*	-.02	.12
Seventh	Size Judgements	.10	.34*	-.19	-.23
Training	Distance Judgements	-.03	-.24	.18	.27
Session	Texture Judgements	.11	-.04	.27	.17

respectively. There are more significant coefficients for distance data than size data and for measures from complete data than from emended data. Both of these differences could be predicted because the linear trend for distance included more of the variance than the linear trend for size and because the response bias serves to fit data to expectation and hence leads to greater consistency of response. The relatively low correlation between stimuli of different magnitudes can be accounted for by postulating different constants for different individuals. The lack of significant relationships between before and after constancy replications at the same magnitude indicates that the measures are not reliable. This provides a further reason for basing the calculation of the Weber constants on the mean of the before and after constancy measures.

Discrimination measures from the size sessions were correlated with the equivalent measures from distance sessions (table 26) to determine whether what was being measured was a general ability to use the Aid, or two independent skills. The low correlations found indicate that the latter was true.

Correlation with Measures of Training

If discrimination and recognition demand similar skills, measures of performance in the training sessions and discrimination sessions should be directly related. Measures of discrimination will be restricted to measures from the emended data in this and all future analyses. Table 27 presents the mean of the correlations of the recognition scores and the measures of discrimination at all three stimuli levels for 16 subjects; df = 42. The only two coefficients to reach $p < .05$ occur in the after constancy measures of size discrimination, which were related to texture recognition in the 6th training session and size recognition in the seventh training session; not even the same measures in the two sessions. It must be remembered, however, that the recognition task was conducted under different circumstances than the discrimination task and this difference may be partially responsible for these results. The lack of any significant improvement with training may also be due, in part, to this lack of relationship between the tasks.

Measures from the Constancy Sessions

Thresholds were taken as; the stimulus evoking the first of two successive "equal" judgements, that evoking the "equal" judgement which was followed by the alternative response, or the point intermediate between two stimuli evoking opposing responses. This differs from the threshold measure used in the discrimination series in that the actual stimulus size is used instead of the point between the stimuli evoking different responses. The latter measure gives a better indication of discrimination but the former is simpler to calculate, does not influence estimates of subjective equality and still gives a satisfactory measure of the area of uncertainty, so long as there is to be no direct comparison with other data.

The range of available stimuli was found to be too small for some subjects to make satisfactory size matches; extreme stimuli sometimes evoked equal judgements and, occasionally, judgements appropriate to the other end of the stimulus range. If the extreme object evoked the response "equal" this stimulus was taken as the threshold value. If it evoked the judgement appropriate to the other end of the scale, the threshold was recorded as the value which would have been accorded the next stimulus if the scale had been extended, i.e., 2 1/4 inches in diameter for the lower threshold and 20 1/4 inches for the upper thresholds.

Analyses of Subjective Equality

Estimates of subjective equality were obtained for each subject for each combination of stimulus size, distance and texture by averaging the four threshold measures, two upper and two lower, obtained. 3 X 2 X 3 X 2 analyses of variance, with repeated measures on the last two variables, were calculated to evaluate the effects of training, background information and changes in the object on estimates of perceived equality of size and distance (tables 28 and 29). The cell entries were estimates of subjective equality from the constancy sessions and from the emended data of the before constancy discrimination sessions with the 9 inch diameter standard and 3 feet standard, for size and distance respectively. These measures were obtained as measures of perceived equality when the objects were equated on all nonjudged variables. These measures were taken from the emended data as this more closely approximated the measures from the constancy sessions. Background information was not altered for these measurements, but as background cues were expected to be important only when the objects differed in more than one way it was assumed that this difference would not invalidate the analyses.

The texture and distance of the standard both influenced perceived size significantly. A larger variable was judged equal to the standard when the latter

TABLE 28

Analysis of Variance of Comparative Size Judgements Under Varying Conditions of Distance and Texture

Source	SS	df	MS	F
<u>Between Subjects</u>	<u>390.591</u>	<u>23</u>		
Training	84.656	2	42.328	$2.565_{(2,18)}$
Background	1.332	1	1.332	<1
Training & Background	7.599	2	3.899	<1
Subjects within groups	297.004	18	16.500	
<u>Within Subjects</u>	<u>1069.245</u>	<u>120</u>		
Distance (of Standard)	215.067	2	107.533	$15.311_{(2,36)}^{**}$
Training X Distance	30.264	4	7.566	$1.077_{(4,36)}$
Background X Distance	0.581	2	0.291	<1
Training X Background X Distance	55.390	4	13.848	$1.972_{(4,36)}$
Distance X Subjects within groups	252.825	36	7.023	
Texture (of Standard)	179.974	1	179.974	$32.758_{(1,18)}^{**}$
Training X Texture	1.160	2	0.580	<1
Background X Texture	0.014	1	0.014	<1
Training X Background X Texture	8.316	2	4.158	<1
Texture X Subjects within groups	98.891	18	5.494	
Distance X Texture	17.008	2	8.504	$1.783_{(2,36)}$
Training X Distance X Texture	23.354	4	5.838	$1.224_{(4.36)}$
Background X Distance X Texture	4.501	2	2.251	<1
Training X Background X Distance X Texture	10.173	4	2.543	<1
Distance X Texture X Subjects within groups	171.727	36		

$^{**}\ p < .01$

GRAPH 12 : SUBJECTIVE EQUALITY OF SIZE AS A FUNCTION OF THE DISTANCE AND TEXTURE OF THE STANDARD.

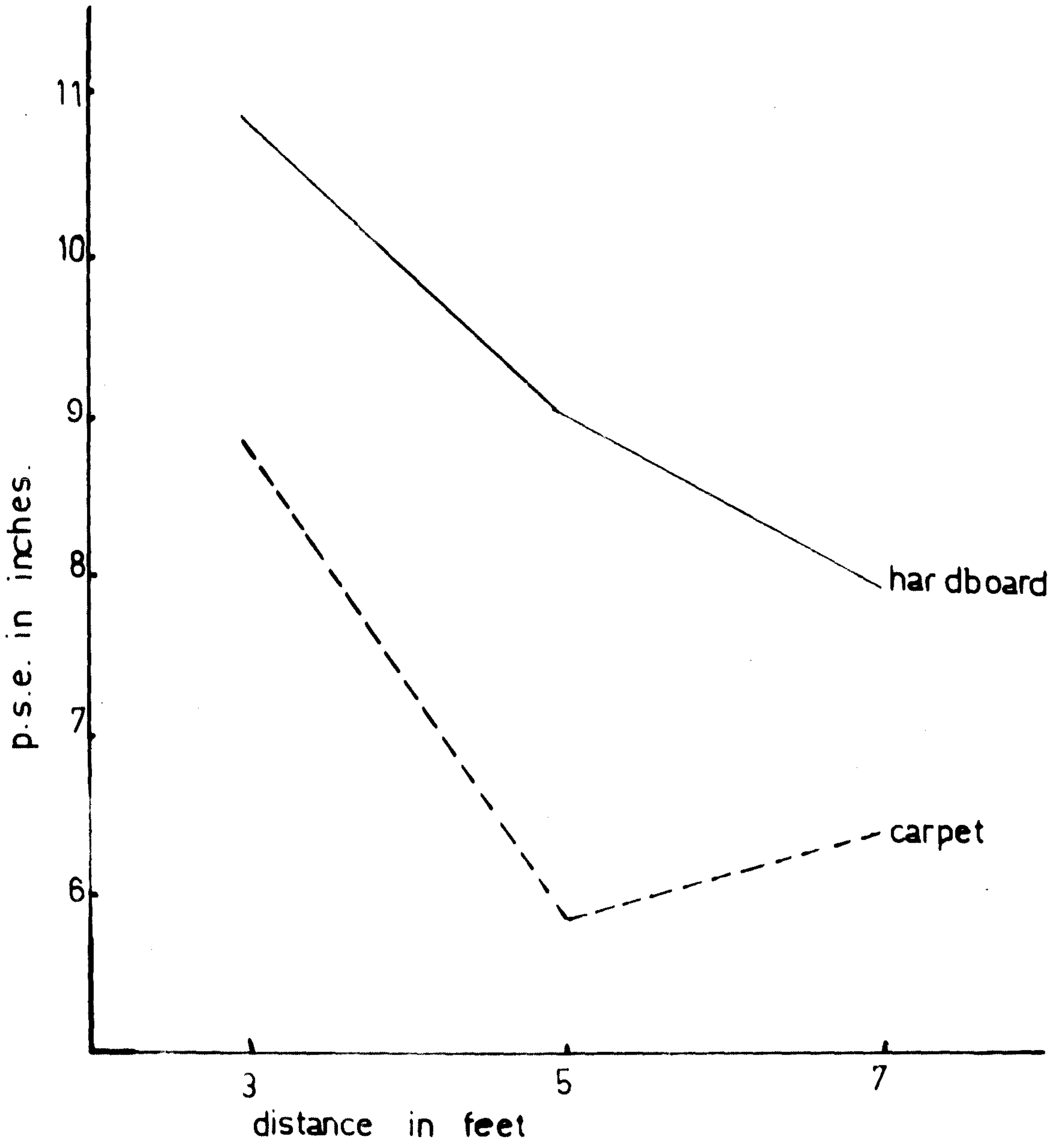


TABLE 29

Analysis of Variance of Comparative Distance Judgements Under Varying Conditions of Size and Texture

Source	SS	df	MS	F
Between Groups	372.404	23		
Training	55.647	2	27.823	$1.718_{(2,18)}$
Background	3.818	1	3.813	<1
Training X Background	21.408	2	10.703	<1
Subjects within groups	291.533	18	16.196	
Within Subjects	1898.559	120		
Size (of Standard)	97.891	2	48.945	$2.392_{(2,36)}$
Training X Size	45.993	4	11.498	<1
Background X Size	42.687	2	21.344	$1.043_{(2,36)}$
Training X Background X Size	56.416	4	14.104	<1
Size X Subjects within groups	736.646	36	20.462	
Texture (of Standard)	156.353	1	156.353	$76.288_{(1,18)}$**
Training X Texture	46.957	2	23.479	$1.146_{(2,18)}$
Background X Texture	40.106	1	40.106	$1.957_{(1,18)}$
Training X Background X Texture	20.048	2	10.024	<1
Texture X Subjects within groups	368.919	18	20.495	
Size Texture	0.286	2	0.143	<1
Training X Size X Texture	23.884	4	5.971	<1
Background X Size X Texture	13.663	2	6.831	$1.025_{(2,36)}$
Training X Background X Size X Texture	8.783	4	2.196	<1
Size X Texture X Subjects within groups	239.927	36	6.665	

** $p < .01$

GRAPH 13: SUBJECTIVE EQUALITY OF DISTANCE AS A FUNCTION OF THE SIZE AND TEXTURE OF THE STANDARD.

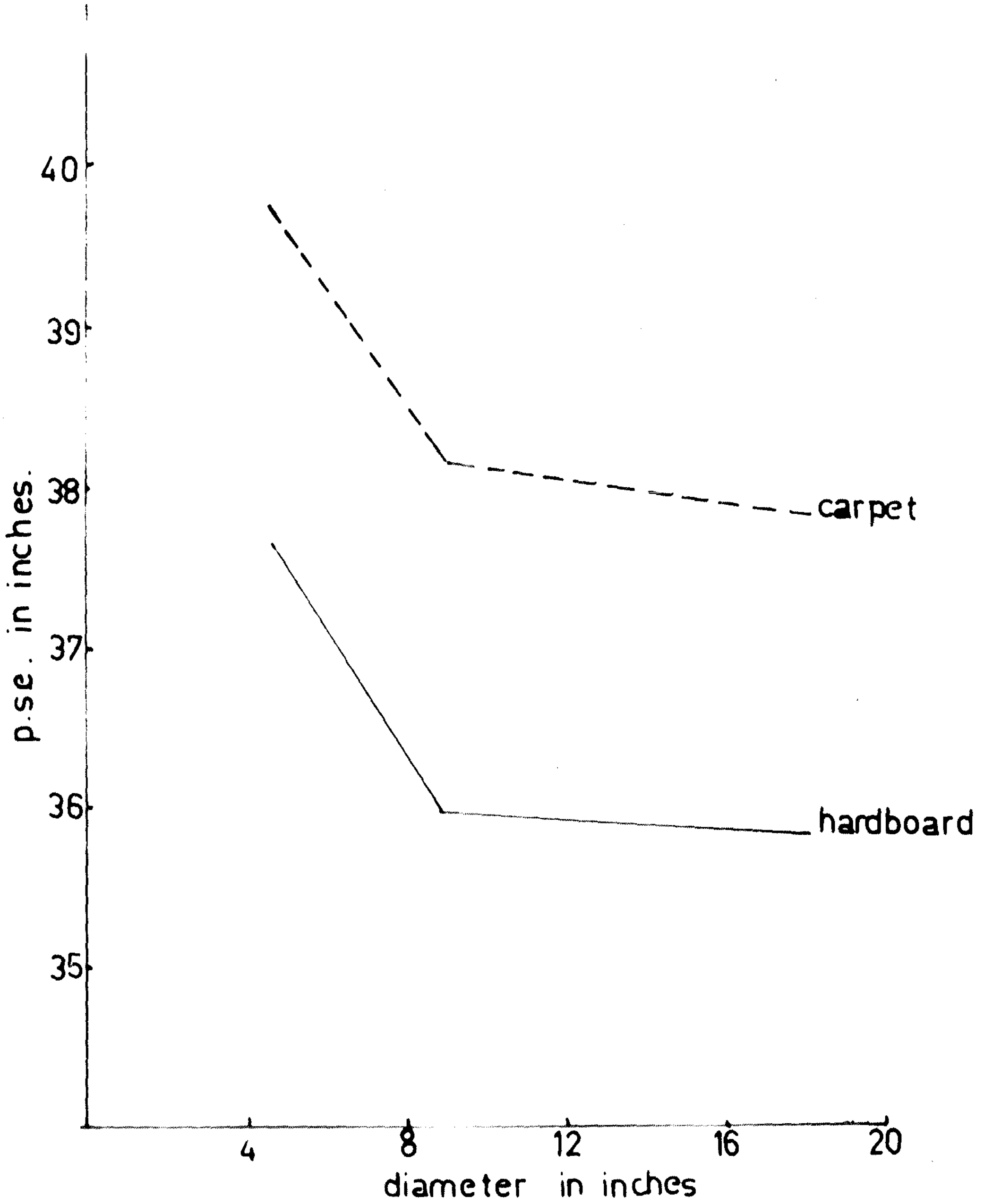


TABLE 30

Mean Size Judgement in Inches When a 9" Object of Differing Textures at Different Distances is Compared with a Hardboard Variable Size at 5'

Texture of Standard	Hardboard			Carpet		
Distance of Standard	3	5	7	3	5	7
Objective size	9	9	9	9	9	9
Subjective size	10.891	9.003	7.904	8.850	5.850	6.395
Angular size	12.000	9.000	6.000			

TABLE 31

Mean Distance Judgement in Inches when a Hardboard Object at 3' is compared with objects of Different Sizes and Textures

Texture of Standard	Hardboard			Carpet		
Size of Standard	4½	9	18	4½	9	18
Objective distance	36.000	36.000	36.000	36.000	36.000	36.000
Subjective distance	37.667	35.972	35.833	39.715	38.178	37.832
Angular distance	72.000	36.000	18.000			

was closer to the Aid and a smaller variable judged equal when the standard was further. A smaller variable was also judged equal to the carpet standard. The lack of a significant interaction of distance and texture of standard suggests that the two effects are additive. This claim is supported by examination of the data (table 29, graph 12) with a non significant departure when the carpet standard was at 7 feet. This discrepancy may be due to the limitations of the stimulus series.

The texture of the standard also affected distance judgements significantly (the carpet disc was seen as further from the Aid than the hardboard one), but the size of the stimuli did not do so. No significant interactions occurred in this analysis and no significant background or training effects were demonstrated in either of these analyses.

Analyses of Uncertainty

In chapter one it was hypothesized that constancy would be related to the degree of confidence with which judgements were made. It was further noted that Cohen, Hershkowitz and Chodack (1958) found that a measure of confidence, the area of uncertainty or difference threshold associated with constancy judgements, to be more sensitive to developmental changes than estimates of subjective equality. The above analyses were, therefore, repeated using measures of the area of uncertainty, associated with each judgement, (determined by differencing the upper and lower thresholds) as cell entries (tables 32 and 33). The measures from the discrimination sessions were adjusted to allow for the different methods of obtaining thresholds. Before these analyses are interpreted it must be emphasized that the limitation of the stimulus range places a ceiling on this measure when the estimate of equality is near the extremes of the stimulus range.

Comparison of the results of the analyses show that for size judgements both perceived equality and the associated area of uncertainty can change significantly with change in the texture or distance of the object. Size and distance do not interact significantly in the analyses of subjective equality but do in the analyses of measures of uncertainty. This interaction stems from the relatively small area of uncertainty associated with the judgements of the carpet standard 7 ft. from the Aid and is probably due to the restriction of the stimulus range.

Judgements of perceived equality of distance were significantly altered by changes in the texture but not the size of the stimuli. The measures of uncertainty

TABLE 32

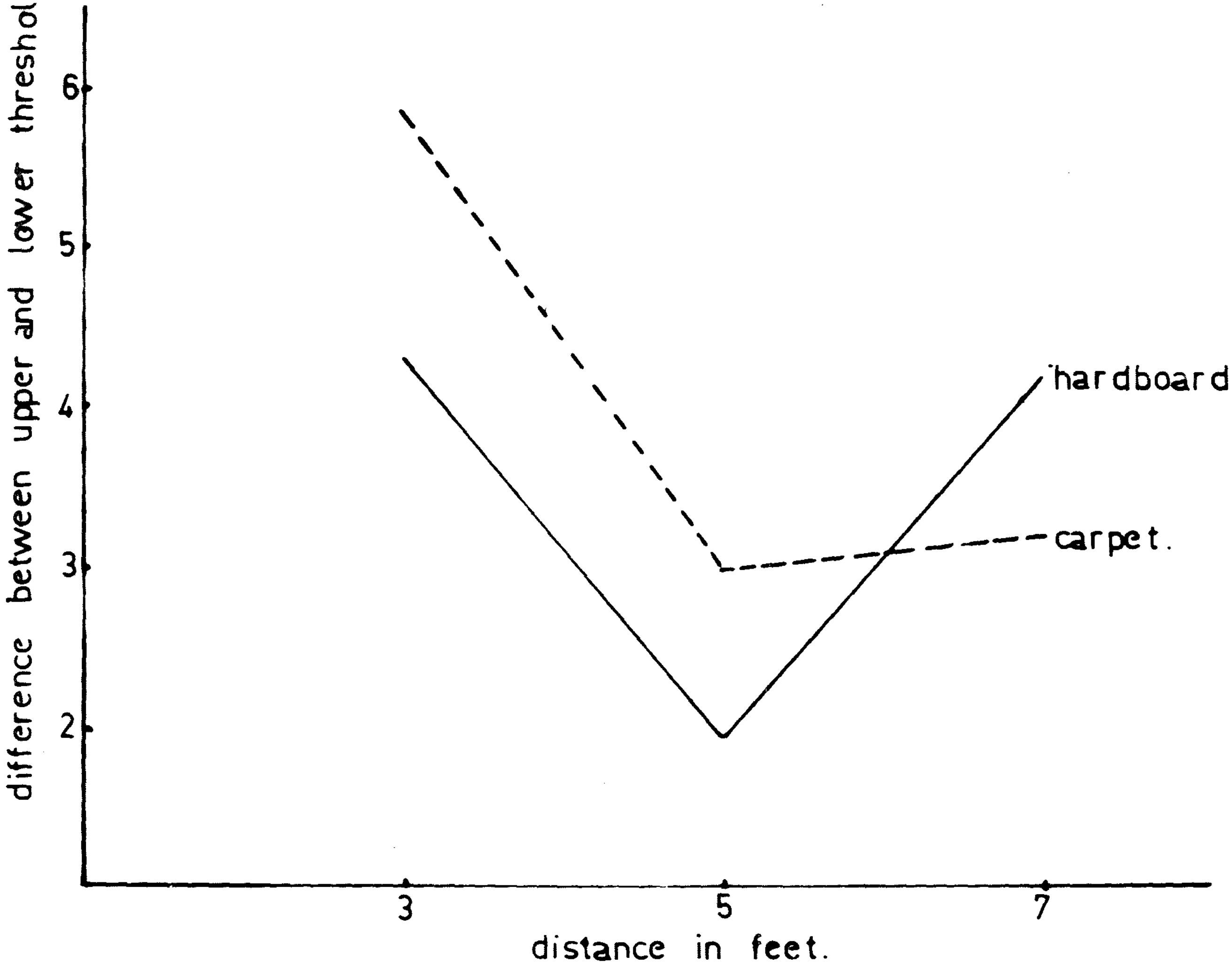
Analysis of Variance of the Area of uncertainty for Size Judgements under Varying Conditions of Distance and Texture

Source	SS	df	MS	F
Between Subjects	499.598	23		
Training	54.569	2	27.285	$2.525_{(2,18)}$
Background	121.497	1	121.497	$11.245_{(1,18)}^{**}$
Training X Background	129.048	2	64.524	$5.972_{(2,18)}^{*}$
Subjects within groups	194.484	18	10.805	
Within Subjects	932.000	120		
Distance (of standard)	207.982	2	103.991	$19.544_{(2,36)}^{**}$
Training X Distance	17.283	4	4.321	<1
Background X Distance	25.430	2	12.715	$2.390_{(2,36)}$
Training X Background X Distance	38.862	4	9.716	$1.826_{(4,36)}$
Distance X Subjects within groups	191.561	36	5.321	
Texture (of standard)	21.067	1	21.067	$4.940_{(1,18)}^{*}$
Training X Texture	.731	2	.367	<1
Background X Texture	6.457	1	6.457	$1.514_{(1,18)}$
Training X Background X Texture	5.944	2	2.972	<1
Texture X Subjects within groups	76.767	18	4.265	
Distance X Texture	56,865	2	28.433	$4.381_{(2,36)}^{*}$
Training X Distance X Texture	10.524	4	2.631	<1
Background X Distance X Texture	.874	2	.437	<1
Training X Background X Distance X Texture	38.024	4	9.506	$1.465_{(4,36)}$
Distance X Texture X Subjects within groups	233.629	36	6.490	

** $p < .01$

* $.05 < p < .01$

GRAPH 14: UNCERTAINTY OF SIZE JUDGEMENTS AS A FUNCTION OF THE DISTANCE AND TEXTURE OF THE STANDARD.



GRAPH 15 : UNCERTAINTY OF SIZE CONSTANCY JUDGEMENTS AS A FUNCTION OF TRAINING AND BACKGROUND

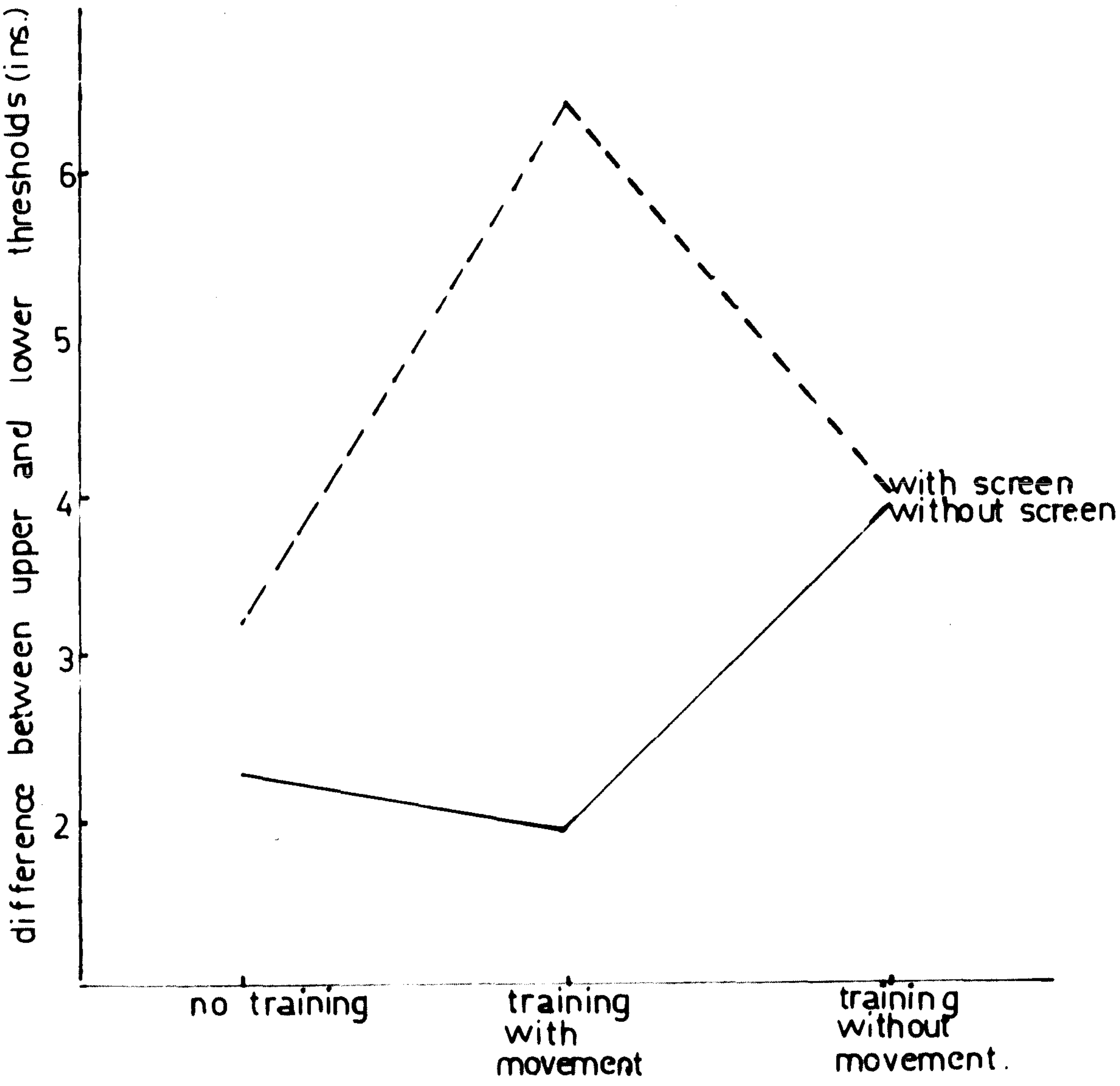


TABLE 33

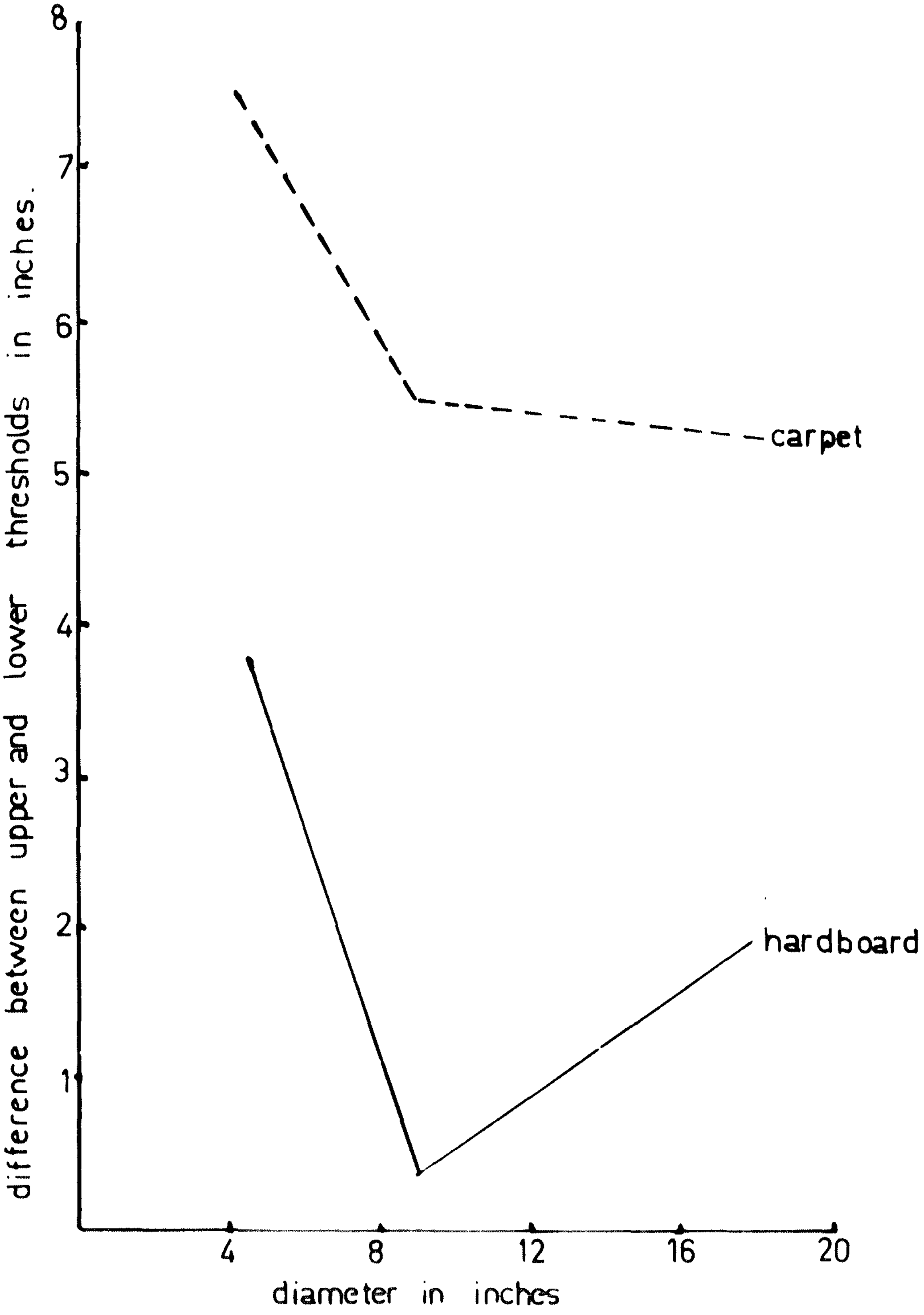
Analysis of Variance of the Area of uncertainty for Distance Judgements under Varying Conditions of Size and Texture

Source	SS	df	MS	F
<u>Between Subjects</u>	<u>2542.175</u>	<u>23</u>		
Training	78.682	2	39.341	<1
Background	179.490	1	179.490	$1.454_{(1,18)}$
Training X Background	62.348	2	31.174	<1
Subjects within groups	221.655	18	123.425	
<u>Within Subjects</u>	<u>4229.870</u>	<u>120</u>		
Size (of Standard)	190.110	2	95.055	$3.839_{(2,36)}$ *
Training X Size	46.064	4	11.516	<1
Background X Size	22.957	2	11.479	<1
Training X Background X Size	196.632	4	49.758	$1.986_{(4,36)}$
Size X Subjects within groups	891.299	36	24.758	
Texture (of Standard)	591.442	1	591.442	$20.479_{(1,18)}$ **
Training X Texture	3.816	2	1.908	<1
Background X Texture	.596	1	.596	<1
Training X Background X Texture	26.174	2	13.087	<1
Texture X Subjects within groups	519.859	18	28.881	
Size X Texture	22.890	2	11.445	<1
Training X Size X Texture	48.927	4	12.232	<1
Background X Size X Texture	63.902	2	31.951	<1
Training X Background X Size X Texture	159.900	4	39.975	<1
Size X Texture X Subjects within groups	1445.302	36	40.147	

** $p < .01$

* $.05 < p < .01$

GRAPH 16 : UNCERTAINTY OF DISTANCE JUDGEMENTS AS A FUNCTION OF THE SIZE AND TEXTURE OF THE STANDARD.



associated with these judgements were influenced significantly by both size and texture. The interaction of size and distance was not significant.

The obtained values of subjective equality are presented in Tables 30 and 31 together with estimates of projective equality for the hardboard standards. The projective size of the carpet objects cannot be estimated yet as the necessary measures of signal changes have not been made. However, as the carpet surface gives a softer signal than the hardboard surface, the projective size match would be smaller than the objective size match and further than the objective distance match. Thus all changes in subjective equality were in the direction of projective matches. The mean deviations from objective equality were not as great as demanded by full projective matches and hence some constancy or trend to objectivity was apparent in the subjects' responses.

The changes in the area of uncertainty were to larger areas of uncertainty with changes in the standard, with the exception of size judgements with the carpet standard at 7 ft. As suggested above, this departure was probably due to the limitation of the range stimuli. Thus uncertainty was greater when constancy was less.

The addition of background cues did not significantly affect the estimates of subjective equality but did lead to significantly greater areas of uncertainty associated with size judgements, indicating that the additional information hinders rather than helps (possibly an overload) when the subjects have had no previous experience of background cues. The influence of background cues on the area of uncertainty associated with size constancy judgements interacts with training. The training group not allowed movement having the smallest areas of uncertainty when no background cues were present and the greatest areas of uncertainty when they were introduced. Thus it would appear that, in this situation, training without movement led to more accurate judgements when the objects differ in more than one way, in those situations where there are no background cues. This skill is disturbed by the introduction of background cues. A plausible reason for this could be that those who were allowed movement in the initial training session were, in fact, overloaded with information and became confused thereby. In the same way, those subjects not allowed movement were perhaps overloaded by the introduction of background cues, the previous trials being very much closer to the training activity.

Interrelationships between Measures of Constancy

The hypothesis, that the confidence with which judgements are made is related to the breakdown of constancy, on which the last two analyses were based, must be tested by correlation of measures of these variables. Estimates of subjective equality were correlated with measures of uncertainty and the signs adjusted to allow for the sign of the difference between objective and projective matches. To aid presentation, the texture difference was assumed to dominate differences in size and distance when they operate in opposing directions, i.e., when size judgements were made with a carpet disc at 3 ft. and distance judgements were made with an 18 inch diameter carpet disc. As it is also of interest to determine if the amount of constancy shown by each subject in each situation was due to a general skill or was peculiar to that specific situation, intercorrelations of all measures from the constancy session were also calculated and presented in table 34.

The two measures from the same constancy data were inversely related when the standard was further or softer than the variable; greater constancy was associated with greater uncertainty. No significant relationship was found when the standard was closer than the variable. The inverse relationship is contrary to expectation but may be due to; the increasing discrimination interval involved in the Weber constants,

TABLE 34

Intercorrelations of Measures of Constancy

n = 24 d.f. = 22

Measure	Judgement	Size, Distance & Texture of Std.	Breakdown of Constancy: Size 3h	7h	5c	7c	3c	Breakdown of Constancy: Distance 4½h	18h	9c	18c	4½c	Area of Uncertainty: Size 3h	7h	5c	7c	3c	Area of Uncertainty: Distance 4½h	18h	9c	18c	4½c
Breakdown of Constancy	Size	3h	-	-.09	-.17	-.33	-.55**	-.11	.01	-.11	.10	.19	.36	-.02	.19	.17	.07	-.11	-.21	-.27	-.21	.22
		7h		-	.17	.43*	.22	.22	.18	.21	.16	.01	-.05	-.60**	.05	-.14	-.43*	.21	.16	.28	.20	.05
		5c			-	.65**	.12	.03	-.04	-.02	.19	-.17	-.21	.08	-.54**	-.01	-.20	.06	-.05	-.11	-.27	-.25
		7c				-	.33	.27	.23	.12	.02	-.30	-.23	-.05	-.41*	-.36	-.04	.25	.19	.30	.10	-.40
		3c					-	-.11	.10	-.21	-.23	-.11	-.10	-.19	-.03	-.59**	-.19	.14	.17	.09	.16	.18
	Distance	4½h						-	.89**	-.45*	-.54**	.29	-.33	.04	-.16	-.04	-.17	.96**	.94**	.72**	.50**	.26
		18h							-	-.44*	-.64**	.24	-.34	.06	-.20	-.09	-.20	.95**	.86**	.75**	.49*	.19
		9c								-	.66**	.11	.17	-.23	.29	.09	.01	-.49*	.42*	.08	-.02	-.24
		18c									-	.16	.31	-.23	.40	.16	.25	-.62**	-.67**	-.47*	-.12	-.11
		4½c										-	.12	.07	.50*	.11	.13	.22	.19	.21	.22	.65**
Area of Uncertainty	Size	3h											-	.21	.65**	.33	.46**	-.36	-.36	-.47*	-.25	-.04
		7h												-	-.13	.38	.71**	.03	.06	-.07	-.08	-.21
		5c													-	.20	.24	-.23	-.16	-.18	.26	.32
		7c														-	.41*	-.08	-.03	-.14	-.01	-.27
		3c															-	-.23	-.24	-.34	-.10	-.24
	Distance	4½h																-	.94**	.74**	.49*	.25
		18h																	-	.80**	.57**	.21
		9c																		-	.63**	.14
		18c																			-	.15
		4½c																				-

* $.05 < p < .01$

** $p < .01$

which would not be insignificant over the stimulus range, the limitation of the response range; and the proximity of projective equality. All these factors may contribute to the trend but the discovery that the relationship was reversed, if not significant, when the hardboard standard was closer than the variable, even though responses were as close to projective equality, indicates that the last factor did not play a dominant role. The wide range of size responses means that many factors and a bipolar trend are influencing results and makes correlations difficult to interpret. The obtained relationships are small so they do not invalidate the interpretation of the overall increase in the areas of uncertainty with changes in size and texture in terms of decreased constancy but does suggest that it should be accepted cautiously.

The correlations between measures from distance judgements are not faced with the same difficulties as those from size judgements as the responses cover a far smaller range. When the objects differ in size alone, or size and texture differences operate in the same direction, increase in the area of uncertainty was significantly associated with a decrease in constancy, as expected. Texture had a significant effect on estimates of perceived equality but size differences alone did not. It would thus appear that the areas of uncertainty associated with perceived equality when judgements were more stable. The increase in uncertainty is probably negatively accelerated enabling individual differences rapidly to swamp other effects. Additional differences to the stimuli can add to the uncertainty, overcoming the individual differences.

Estimates of the breakdown of size constancy tend to be significantly related to other such measures taken from judgements made at the same distance. The estimates determined from measures taken with the standard closer than the variable, (i.e., when the projective match is in the opposite direction to the other situations) were inversely related to the other measures, which were directly related to each other. This suggests that the measures were partly dependent on a general tendency to over- or underestimate the variable relative to the standard. The areas of uncertainty were significantly related to measures taken when the standard was three feet from the Aid. All measures tended to be positively associated.

Estimates of the breakdown of distance constancy tended to be directly related when judgements were made with a standard of the same texture and inversely related when taken with standards of different textures. Judgements made when the standard is a 4½ inch diameter carpet disc, i.e., when differences supplement each other, were not significantly related to any other measures. The highest correlations occur when both measures were taken with hardboard standards. The maintenance of distance constancy with changes in size or texture tended to be opposing skills.

There was no consistent relationship between measures from judgements of size and judgements of distance indicating that these were two independent skills.

<u>The Relation of Measures of Constancy to other Measures</u>

Measures external to the constancy sessions can provide some information as to the ease with which size and distance were judged when other variables were kept constant (discrimination sessions) and when the task was different (Training sessions). Measures from these sessions were correlated with measures from the constancy sessions and the resulting coefficients presented in Tables 35 - 37.

Measures of discrimination were not significantly associated with measures of the breakdown of constancy (Table 35). This was expected because the size and

TABLE 35

Correlations of Measures of Constancy and Discrimination

n = 24 d.f. = 22

Size Constancy

Judgement	Measure Replication	Size, Distance & Texture of Std.	Breakdown of Constancy 3h	7h	5c	7c	3c	Area of Uncertainty 3h	7h	5c	7c	3c
Size Discrimination	Before Constancy	4½	.11	.31	-.09	.09	-.21	.12	.03	.11	.42*	-.09
		9	.10	-.17	.18	.11	0	.53**	.14	.26	.21	.39
		18	.01	-.02	.06	.24	.04	.21	.32	.00	.15	.30
	After Constancy	4½	.01	.06	.27	.04	0	.31	.28	.04	.46*	.39
		9	-.08	-.08	-.00	.00	-.19	.16	.29	.09	.20	.22
		18	.34	-.07	.07	-.15	-.20	.33	.08	.02	.29	.00
Distance Discrimination	Before Constancy	3	-.29	-.05	.10	-.10	.05	-.27	.16	-.14	-.03	.11
		5	-.05	-.07	-.03	-.29	-.12	-.12	.29	.01	.24	.09
		7	.01	.10	-.04	-.26	-.34	-.15	-.02	-.11	.24	-.04
	After Constancy	3	-.06	.09	-.31	-.20	-.27	-.18	.00	-.12	.23	-.27
		5	-.01	.02	-.13	-.14	-.29	-.08	.17	-.06	.11	-.06
		7	-.18	.14	.05	-.01	-.02	.00	.08	.05	-.09	-.03

Distance Constancy

Judgement	Measure Replication	Size, Distance & Texture of Std.	Breakdown of Constancy 4½h	18h	9c	18c	4½c	Area of Uncertainty 4½h	18h	9c	18c	4½c
Size Discrimination	Before Constancy	4½	.15	.22	.22	.25	.18	.16	.06	.21	.26	-.17
		9	-.37	-.42*	.27	.44*	-.11	-.39	-.42*	-.45*	-.22	-.32
		18	.22	.30	-.13	-.09	-.16	.22	.19	.07	.12	-.30
	After Constancy	4½	.21	.11	-.37	-.14	.10	.17	.16	-.24	-.23	.09
		9	.13	.03	.05	-.06	.21	.04	.04	-.10	-.33	-.13
		18	.00	.00	-.01	.01	-.10	-.07	-.08	-.19	-.38	-.17
Distance Discrimination	Before Constancy	3	-.18	-.29	-.02	.25	.02	-.24	-.18	-.14	.09	.03
		5	-.08	-.05	-.08	.14	.18	-.03	-.04	-.03	.28	.12
		7	-.26	-.20	.22	.17	-.06	-.21	-.17	.08	.19	-.06
	After Constancy	3	-.01	-.01	.09	-.17	-.20	-.02	.13	.23	.16	-.18
		5	-.04	-.25	-.05	.02	.00	-.16	.01	-.06	-.06	.13
		7	-.14	-.41*	.02	.17	.02	-.24	-.09	-.18	-.14	.24

** $p < .01$

* $.05 < p < .01$

TABLE 36

Correlations of Measures of Constancy and the Variance of Discrimination Data

$6 \times n = 24$ d.f. = 132

Size Judgements

Measures	Replication	Breakdown of Constancy					Area of Uncertainty				
		Distance in ft. & texture of std.									
		3h	7h	5c	7c	3c	3h	7h	5c	7c	3c
Variance of Complete Data	Before Constancy	.04	.24**	.25**	.37**	.03	.18*	.09	.04	.06	.23**
	After Constancy	.07	.02	.25**	.25**	.01	.21*	.33**	-.02	.23**	.32**
Variance of Emended Data	Before Constancy	.14	.02	.03	.03	.20	.23**	.06	.16	.01	.07
	After Constancy	.12	-.07	.26**	.12	.05	.12	.30**	.01	.10	.35**
Response Bias	Before Constancy	.06	.16	.25**	.38**	.06	.09	.21*	-.07	.10	.25**
	After Constancy	.06	.11	.22**	.23**	.01	.08	.10	-.06	.22**	.11

Distance Judgements

Measures	Replication	Breakdown of Constancy					Area of Uncertainty				
		Diameter in ins. & texture of std.									
		4½h	18h	9c	18c	4½c	4½h	18h	9c	18c	4½c
Variance of Complete Data	Before Constancy	-.03	-.02	.08	.09	.16	.02	-.04	.10	.13	.00
	After Constancy	-.05	-.14	.00	.02	.08	.03	-.06	.03	.00	.07
Variance of Emended Data	Before Constancy	-.03	-.04	.10	.02	.19*	-.03	-.03	.06	.00	.06
	After Constancy	-.07	-.10	-.02	.06	.01	-.08	-.07	-.12	.15	.00
Response Bias	Before Constancy	-.11	-.11	.11	.22**	.14	-.01	-.16	-.05	.09	-.21*
	After Constancy	.09	-.05	.04	-.07	.23**	.00	.11	-.02	-.01	.19*

** $p < .01$ * $.05 < p < .01$

TABLE 37

Correlations of Measures of Constancy and Measures of Performance at the end of Training

$n = 16 \quad d.f. = 14$

Size Constancy

	Measures Judgements	Breakdown of Constancy Distance & Textures of Std. 3h	7h	5c	7c	3c	Area of Uncertainty 3h	7h	5c	7c	3c
Sixth Training Session	Size	-.19	-.18	.73**	.41	-.32	-.16	-.01	-.32	.22	.25
	Distance	-.33	-.14	.04	.27	-.42	.06	-.08	.11	.17	-.03
	Texture	.05	-.25	.30	-.06	-.14	-.02	.05	.07	.09	.34
Seventh Training Session	Size	.12	-.31	.67**	.28	-.09	-.23	.16	-.40	.04	.25
	Distance	-.21	.05	.07	.23	-.29	-.16	-.06	-.07	-.01	-.07
	Texture	-.14	.23	-.10	-.00	.35	.21	.13	-.09	.09	.08

Distance Constancy

		Breakdown of Constancy Size & Texture of Std. 4½h	18h	9c	18c	4½c	Area of Uncertainty 4½h	18h	9c	18c	4½c
Sixth Training Session	Size	.06	-.24	.34	.41	.03	-.16	-.06	.00	-.28	-.10
	Distance	.46	.10	.54*	.24	.20	.21	.21	.21	.20	-.11
	Texture	.09	.39	.04	-.34	.41	-.27	-.16	-.16	-.26	-.26
Seventh Training Session	Size	-.10	-.05	.04	.19	-.06	-.12	-.17	-.15	-.35	-.01
	Distance	.31	-.14	.33	.25	.11	.12	.18	.31	.38	-.02
	Texture	.06	.05	.14	.09	.24	.06	-.02	.16	.11	.08

** p .01

* .05 p .01

distance differences of the standard and variables in the constancy session were much greater than 1 j.n.d.. Little association was found between measures of discrimination and the measures of uncertainty from the constancy sessions. This is more surprising because these are essentially similar measures. Distance discrimination was not related to any of the measures of constancy but the before constancy measures of size discrimination with the same size standard (9" diameter) as the constancy sessions were related to uncertainty of size constancy judgements with the hardboard standard at 3 ft. Size discrimination with the 4½ inch standard (before and after constancy) was associated with the uncertainty of constancy judgements with the carpet standard at three feet. Thus, discrimination measures with small standards were associated with the uncertainty of the smaller estimates of equality and discrimination measures of larger objects with uncertainty of the larger estimates of equality. This finding offers some support for the claim that the inverse relation of breakdown of size constancy and uncertainty is partly due to the operation of Weber's Law. Size discrimination was also related to both measures of distance constancy, this relationship was not significant at the 1% level and is probably unimportant. The less fine the discrimination the greater the constancy with changes in size.

Measures of the variability of responses in the discrimination sessions were obtained as an estimate of the ease of such judgements. These measures were correlated with measures from the constancy sessions and the averages of six coefficients (upper and lower thresholds from each standard magnitude) are presented in Table 36. As the total variance from these responses has been shown to be due to two factors, a response bias and the variability of the first response change (from the emended data), these measures were also correlated with the measures from the constancy sessions and are presented in the same table.

Distance constancy was little related to variability of distance discrimination responses but size constancy was related to the variability of size discrimination responses. The variance of the complete data from size discrimination sessions was related to the breakdown of constancy when the standard was further than the variable and when the standard and the variable differ in texture alone (greater variance is associated with less constancy). Measures of this variance from the before constancy sessions were also related to measures of the areas of uncertainty associated with constancy judgements, when the standard is closer than the variable. The variance from the after constancy discrimination sessions was associated with all areas of uncertainty except those obtained when the stimuli differ in texture alone. Thus at least one of the measures from each of the constancy sessions is related to the total variance of the discrimination judgements. When the variance was split neither part was as highly correlated as the whole and the measure of constancy was more highly related to the measure of response bias.

The relationship of performance during the training tasks to performance in the constancy sessions is examined in Table 37. Judgements of size, in both training sessions, and distance, in the sixth training session were significantly associated with size and distance constancy respectively when the standard differs in texture alone; less error in training is associated with greater constancy. They are not related to the measures of uncertainty. Performance external to the constancy session was again related to size constancy.

The Questionnaire

EASE OF JUDGEMENT

In the questionnaire the subjects were asked to rank size and distance according to the ease of judgement. All but two of the subjects, both in the no training group, rated size as the more difficult. Texture was also ranked by the subjects from the training groups and was placed intermediate between distance and size by 12 out of 16 subjects. Thus, for most subjects, distance judgements were thought to be easiest, and size judgements the most difficult.

The subjects were also required to rate each type of judgement for ease of judgement on a nine point scale from extremely easy to extremely difficult. The ratings were scaled from 1-9 in this direction. The mean and standard deviations of the ratings of each judgement follow:

Ease of judgement rating	Mean	s.d.
Size	5.913	1.868
Distance	3.333	1.375
Texture	4.703	1.248

These ratings were obtained in addition to the ranks as they are more sensitive and hence can be used to examine the relationship of subjective confidence in making these judgements to actual performance. The subjects who had no training did not make any texture judgements and could not, therefore, rate texture so the correlations with this measure are based on 16 subjects (d.f. = 14) while the correlations with other measures are based on 24 subjects (d.f. = 22).

Interrelations of Ratings

The intercorrelations among these measures, presented in table 38, show that while size and distance and distance and texture ratings are reasonably independent, size and texture are significantly correlated; those subjects who rated size highest rated texture lowest. These two measures are, thus, not fully independent, possibly because the cues on which they are based are not independent.

TABLE 38

Intercorrelation of ease of Judgement Ratings.

	Size	Distance	Texture
Size	-	-.21	-.52*
Distance		-	.13
Texture			-

* $.05 < p < .01$

Relationship of Ratings to other Measures

The correlations of ratings of subjective confidence and measures of performance are found in Table 39. Ease of texture judgements was not correlated with discrimination measures as texture was equated in all these sessions. Few significant correlations were found, possibly because of the low variance of the ratings and the general agreement as to the rank order of the different judgements.

Texture judgements in both training sessions were related to ease of judgement ratings; ease of texture ratings in the sixth training session and ease of size judgements in the seventh session; better performance was associated with greater ease of texture judgements and less ease of size judgements. This is consistent with the negative correlation between these two ratings.

The only measure from the discrimination sessions that was significantly related to ease of judgement ratings was response bias. Response bias in both size and distance discrimination judgements was related to ratings of ease of size judgement; subjects ranking size judgements as being easier showed less response bias for distance judgements and more for size judgements. This indicates that the rating of ease of judgements may reflect the response strategy used.

TABLE 39

Correlations between Ratings of Subjective Confidence and Measures of Performance with the Aid

Measures of Performance with the Aid				Ratings of Subjective Confidence: Size Judgements	Distance Judgements df=22		Texture Judgements df=14	
Training Sessions	Sixth Session	Size Judgements		.26	-.21		-.09	
		Distance Judgements		-.05	.03		.43	
		Texture Judgements		-.46	-.06		.55*	
	Seventh Session	Size Judgements		.17	.11		-.18	
		Distance Judgements		-.07	-.02		.23	
		Texture Judgements		-.53*	.04		.37	
Discrimination Sessions	Size Judgements	j.n.d.	before constancy	.21	-.10	df=66		
			after constancy	.14	-.16			
		Variance of complete data	before constancy	.12	.05	df=132		
			after constancy	.17	-.08			
		Variance of emended data	before constancy	-.05	.00			
			after constancy	.08	.03			
		Response bias	before constancy	.19	-.13			
			after constancy	.12	-.13			
	Distance Judgements	j.n.d.	before constancy	.21	-.10	df=66		
			after constancy	.14	-.16			
		Variance of complete data	before constancy	.01	-.03	df=132		
			after constancy	-.13	-.05			
		Variance of emended data	before constancy	-.13	-.04			
			after constancy	-.06	-.11			
		Response bias	before constancy	-.08**	-.11			
			after constancy	-.25	.02			
Constancy Sessions	Size Judgements	Breakdown of Constancy	Distance & texture of std.					
			3h	.00	.02	df=22	-.05	df=14
			7h	-.20	-.05		.00	
			5c	.25	.08		.06	
			7c	.19	.00		.26	
			3c	.16	.24		.06	
		Area of Uncertainty	3h	-.06	-.14		.20	
			7h	-.34	.23		.18	
			5c	.33	.20		.20	
			7c	.39	.56**		.24	
			3c	.23	.42*		.02	
	Distance Judgements	Breakdown of Constancy	Size & texture of std.					
			$4\frac{1}{2}$h	.17	-.30		.13	
			18h	.22	-.21		-.02	
			9c	-.20	.20		-.24	
			18c	-.14	.07		.12	
			$4\frac{1}{2}$c	-.32	-.01		.25	
		Area of Uncertainty	$4\frac{1}{2}$h	.18	-.24		.01	
			18h	-.13	.29		.04	
			9c	.01	-.10		.10	
			18c	-.05	-.30		-.01	
			$4\frac{1}{2}$c	-.59**	.09		.08	

* $.05 < p < .01$

** $p < .01$

Measures of constancy were not related to ease of judgement ratings but the measures of uncertainty obtained when the objects differ in both size or distance and texture were, particularly when the two cues supplement each other. Greater uncertainty was associated with greater subjective ease of size judgements for distance constancy and distance judgements for size constancy. Apparently greater confidence in identifying the non judged attributes of stimuli led to lessened constancy. This may be a contrast effect or be due to the amount of distraction occasioned by the nonjudged variable.

RATING OF CRITERIA USED IN MAKING JUDGEMENTS

Subjects were also asked to state which criteria they used in making the different judgements, and to rank them in order of importance, given the choice of: pitch, loudness, scanning width, timbre and an empty category. The empty category was never used and the frequencies with which each of the categories was marked as being used and the rank accorded each are shown in Table 40, graph 18.

TABLE 40

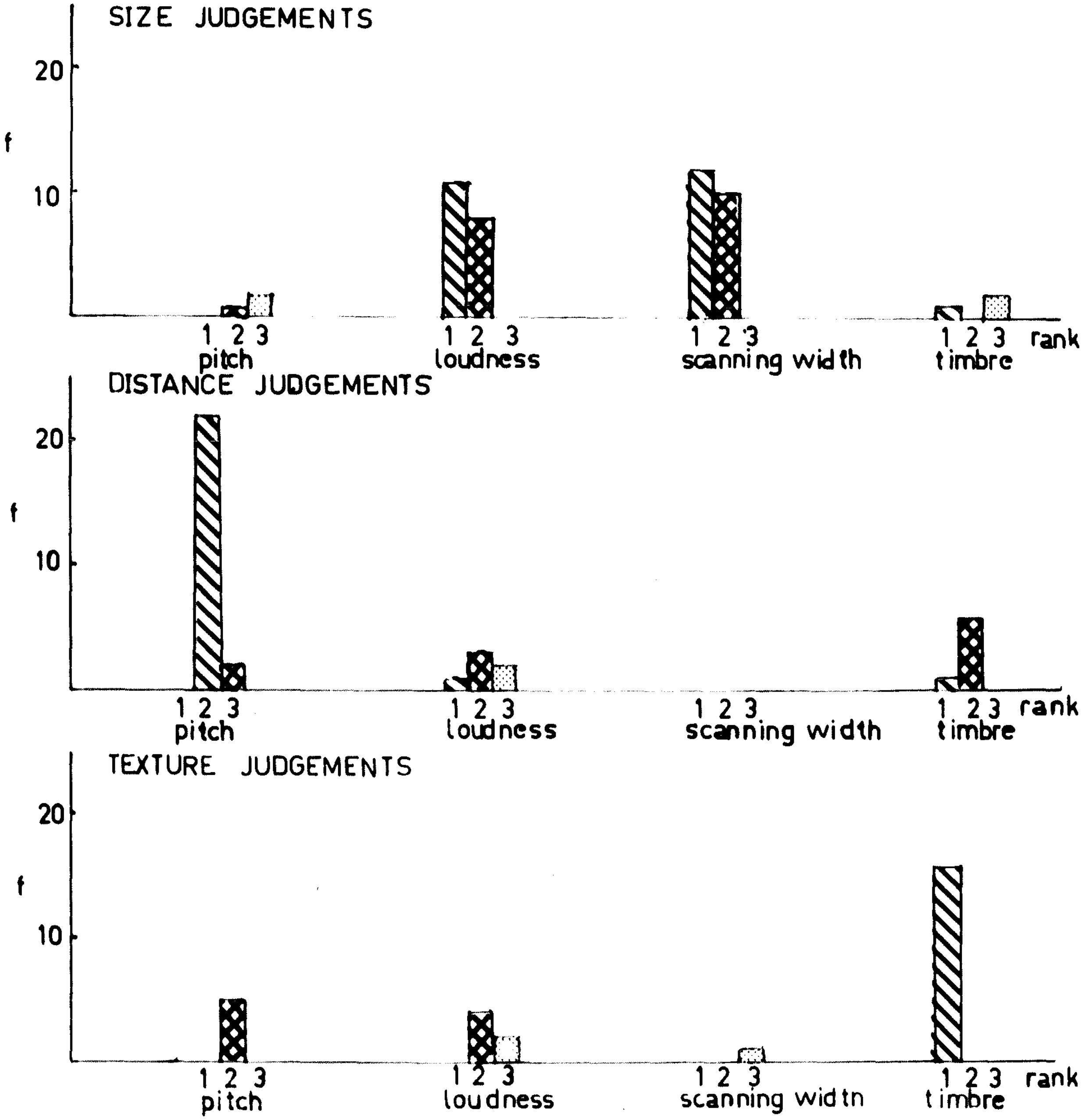
Rating of Criterion used in Making Judgements

Categories	Pitch	Loudness	Scanning Width	Timbre	
Distance Judgements					
Rank 1	22	1		1	
2	2	3		6	
3		2			N = 24
Size Judgements					
Rank 1		11	12	1	
2	1	8	10		
3	2			2	N = 24
Texture Judgements					
Rank 1				16	
2	5	4			
3		2	1		N = 16

Only 16 subjects ranked texture as the training groups made no texture judgements.

There is considerable agreement among subjects as to the criteria used in making distance and texture judgements, most subjects using only one criterion. However, there is a division among subjects as to the major cue for size; most subjects using both loudness and scanning width but placing different values on the importance of each.

GRAPH 18: SUBJECTS' RANKING OF THE CUES FOR THE DIFFERENT JUDGEMENTS



Measures of Individual Differences

These were obtained to discover whether ability to use the Aid could be predicted from measures of audition and of personality.

AUDITION

Raw scores are used in all analyses of the data from the subtests of the Seashore Measures of Musical Talents as Riley, Gunther, and Cohen (1966) use the raw scores in their discussion of the relationship of these measures and mobility with the Aid.

An analysis of variance of the change in scores, with direction of change considered, between measurements of the tests before the subjects had any experience with the Aid and near the end of experimentation for the different training groups and the control group appears in Table 41. The different numbers in the experimental and control groups were corrected by the unweighted means solution (Winer, 1962 p.375). There is no significant difference when all groups are compared, but when the combined experimental groups are tested against a weighted control score a significant difference was found, with the experimental groups showing an increase in discrimination over time and the control groups a decrease for all but the pitch test (table 42). This means that, when

TABLE 41

Analysis of Variance of Change in Performance on the Seashore Measures of Musical Talents

Source	SS	df	MS	F
<u>Between Subjects</u>		<u>42</u>		
Group	114.488	3	38.163	$1.838_{(3,39)}$
Subjects within groups	809.726	39	20.762	
<u>Within Subjects</u>		<u>86</u>		
Subtest	6.131	2	3.066	1
Group by Subtest	92.161	6	15.360	1
Subtest X Subjects with groups	1256.485	78	16.109	
Control X Comparison	94.831	1	94.831	$4.568_{(1,39)}$*

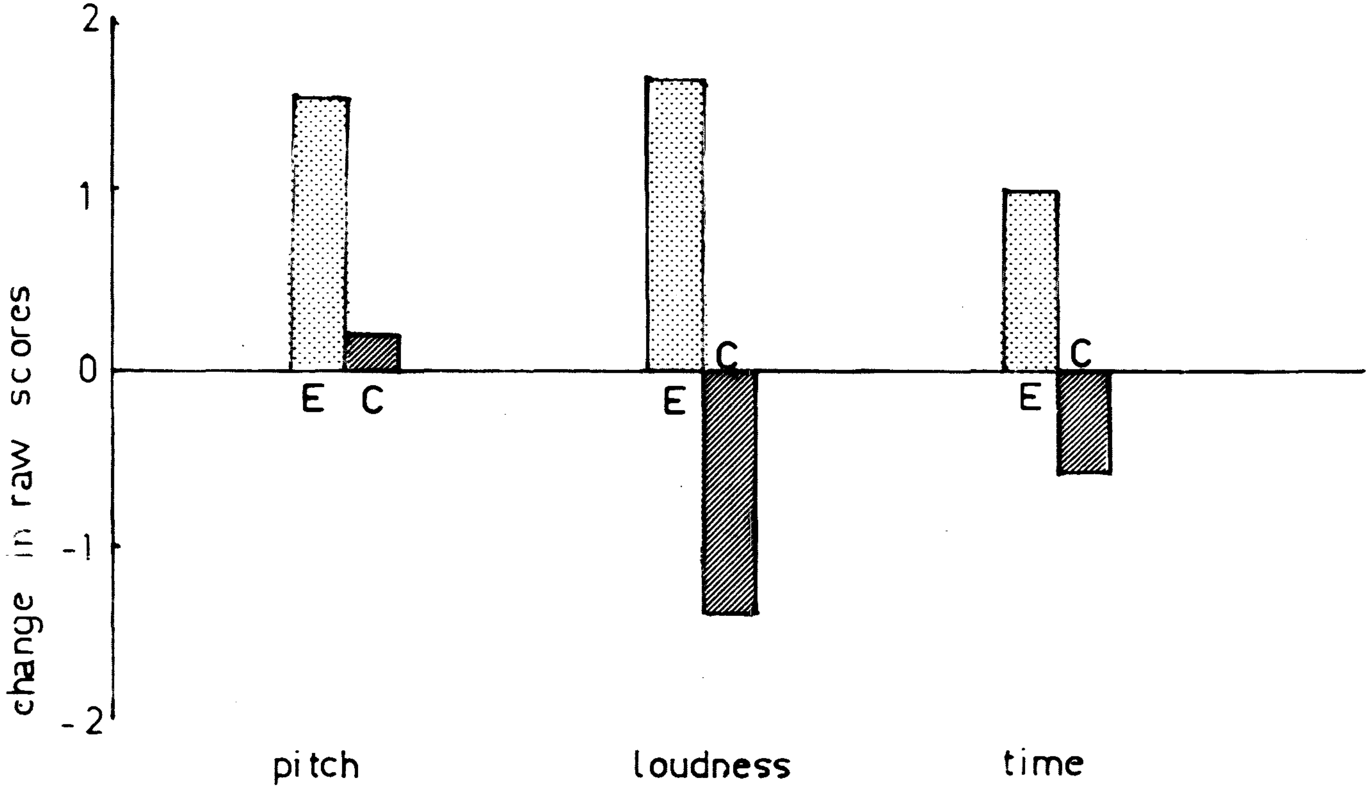
* $.05 < p < .01$

TABLE 42

Scores on the Seashore Measures of Musical Talents

Subtest	Pitch	Loudness	Time	Timbre
Experimental Groups				
Before Experimentation	40.37	41.70	40.58	
After Experimentation	41.66	43.37	41.62	39.66
Control Group				
Before Experimentation	41.63	41.81	39.68	
After Experimentation	42.00	40.47	39.31	39.42

GRAPH 17 : CHANGE IN PERFORMANCE ON THE SEASHORE MEASURES OF MUSICAL TALENTS AS A FUNCTION OF EXPERIENCE WITH THE AID.



E = the experimental group
C = the control group

considering the role that such measures can play in predicting performance with the Aid, before the subject has had any experience with it, interest must be restricted to the relationships with the first measures.

A measure of auditory acuity was obtained for the experimental subjects by summing the measures from each frequency level on the Audiometer test; a high score indicating poor acuity. As no subjects showed large variations between frequencies, this combination score provides a satisfactory measure of general acuity.

Interrelationship of Auditory Measures

Intercorrelation of measures of auditory discrimination from the 'Seashore' for; the control group, the experimental group, and the combined groups are presented in Table 43. The correlations between the same measures over time for all groups are considerably lower than the reliability coefficients quoted by Seashore, Lewis and Saetveit (1960), especially for the loudness test which fails to reach significance for either group of subjects. Pitch was the only test to display satisfactory reliability. Intercorrelations of the different measures both within and between sessions, were large, especially for time and loudness indicating that the measures are not

TABLE 43

Intercorrelations of the Seashore Measures of Musical Talents

Control Group n = 19 d.f. = 17

		Before Experimentation Pitch	Before Experimentation Loudness	Before Experimentation Time	After Experimentation Pitch	After Experimentation Loudness	After Experimentation Time	After Experimentation Timbre
Before Experimentation	Pitch	–						
	Loudness	.13	–					
	Time	.32	.70**	–				
After Experimentation	Pitch	.80**	.33	.46*	–			
	Loudness	.22	.36	.56*	.48*	–		
	Time	.16	.37	.45	.34	.65**	–	
	Timbre	.61**	.37	.65**	.52*	.39	.44	–

Experimental Groups n = 24 d.f. = 22

		Before Experimentation			After Experimentation			
Before Experimentation	Pitch	–						
	Loudness	.20	–					
	Time	.28	.33	–				
After Experimentation	Pitch	.71**	.30	.23	–			
	Loudness	.36	.15	.51*	.38	–		
	Time	.32	.14	.66**	.21	.53**	–	
	Timbre	.27	.07	.10	.32	.32	.37	–

All Subjects n = 43 d.f. = 41

		Before Experimentation			After Experimentation			
Before Experimentation	Pitch	–						
	Loudness	.17	–					
	Time	.26	.56**	–				
After Experimentation	Pitch	.74**	.31*	.32*	–			
	Loudness	.21	.24	.53**	.37*	–		
	Time	.20	.25	.52**	.25	.63**	–	
	Timbre	.41**	.24	.49**	.40**	.34*	.40**	–

* p < .01   ** .05 < p < .01

TABLE 44

Correlation of Auditory Measures with Measures of Performance with the Aid

Measures of Performance with the Aid			Auditory Measures	Before Experimentation Pitch	Before Experimentation Loudness	Before Experimentation Time	After Experimentation Pitch	After Experimentation Loudness	After Experimentation Time	After Experimentation Timbre	Acuity	df=14
Training Sessions	Sixth Session	Size Judgements		.21	-.15	.11	.18	-.06	.18	0	.31	
		Distance Judgements		-.23	-.06	.21	-.20	-.05	.32	-.47	.34*	
		Texture Judgements		-.13	-.19	.10	-.05	-.05	.08	-.45	-.08	
	Seventh Session	Size Judgements		.22	-.08	.05	.36	.16	.16	.01	-.10	
		Distance Judgements		-.39	-.48	-.26	-.45	-.26	.05	-.51*	.28	
		Texture Judgements		-.53*	-.41	-.19	-.44	-.27	-.32*	-.38*	.05	
Discrimination Sessions	Size Judgements	j.n.d.	before constancy	.15	-.08	.04	.16	-.09	-.07	-.13	-.12	df=66
			after constancy	.32*	.28*	.38**	.41**	.19	.13	.19	.04	
		Variance of complete data	before constancy	-.13	.05	-.06	.20*	-.11	-.07	-.19*	.20	df=132
			after constancy	.24**	.13	.28**	.24**	.05	.17	.02	.11	
		Variance of emended data	before constancy	.10	.05	-.08	.21	-.03	-.01	.05	.01	
			after constancy	.14	.06	.01	.14	-.02	.04	-.16	.17	
		Response bias	before constancy	.08	-.13	.03	.03	-.16	-.11	-.27**	.21*	
			after constancy	.07	.05	.28**	.05	-.03	.14	-.16	.05	
	Distance Judgements	j.n.d.	before constancy	-.55**	-.12	-.23	-.52**	-.41**	-.31**	-.21	.01	df=66
			after constancy	-.49**	-.07	-.11	-.38**	-.22	-.12	-.09	.23*	
		Variance of complete data	before constancy	-.04	.02	-.17	-.38**	-.21	-.37**	-.28**	.06	df=132
			after constancy	-.28**	-.18*	-.07	-.25**	-.17	.07	-.11	-.12	
		Variance of emended data	before constancy	-.18*	-.19*	-.06	-.09	-.04	-.18*	-.18*	.11	
			after constancy	-.12	-.16	-.24**	-.22*	-.25**	-.25**	-.14	-.14	
		Response bias	before constancy	-.31**	.03	-.04	-.28**	-.24**	-.35**	-.46**	.02	
			after constancy	-.18*	-.17	.06	-.23**	.03	-.05	-.13	.07	
Constancy Sessions	Size Judgements	Breakdown of Constancy	3h	.08	-.14	-.13	.13	-.16	.00	.11	.39	df=22
			7h	.15	-.21	.20	.07	.12	.17	-.06	-.10	
			5c	-.25	-.06	-.15	-.35	-.10	-.07	.09	-.03	
			7c	-.26	.06	-.23	-.10	-.11	-.13	.16	-.13	
			3c	-.15	.00	.09	-.04	-.37	-.05	-.05	.54**	
		Area of Uncertainty	3h	.36	.24	.25	.36	.24	.33	.02	.07	
			7h	.53	.14	.39	.09	.11	.28	-.02	-.02	
			5c	.02	.08	-.25	.00	-.13	.09	-.08	.34	
			7c	.19	.31	.11	.15	-.27	.07	-.07	.22	
			3c	.47*	.04	.19	.27	-.06	.17	-.28	.14	
	Distance Judgements	Breakdown of Constancy	$4\frac{1}{2}$h	.18	.06	-.01	-.14	-.03	.03	.03	.29	
			18h	-.24	-.08	.08	.10	-.03	.06	-.14	.00	
			9c	-.28	-.12	-.03	-.17	-.08	.06	-.15	.21	
			18c	-.26	-.06	-.18	.02	-.36	-.12	-.32	.23	
			$4\frac{1}{2}$c	-.07	.09	-.38	-.16	-.23	.02	.07	.09	
		Area of Uncertainty	$4\frac{1}{2}$h	.20	.10	-.05	-.10	.06	-.05	.10	.02	
			18h	.14	.04	.01	-.23	.09	.06	.11	.07	
			9c	-.10	-.13	-.11	-.48*	-.01	.01	.05	.13	
			18c	-.16	-.25	-.48*	-.52**	-.35	-.12	-.26	.08	
			$4\frac{1}{2}$c	-.26	-.03	-.50*	-.20	-.07	-.15	.19	-.10	
Ease of Judgement Ratings	Size			.56**	.05	.21	.38	.04	.32	.14	.04	
	Distance			-.37	-.21	.01	.01	.41*	.05	.21	-.05	
	Texture			-.17	.24	-.14	.25	.48	-.24	.13	-.30	df=14

* $.05 < p < .01$

** $p < .01$

independent. Pitch and time discrimination were both related to Timbre discrimination for the control group, but not for the experimental group. Practice with the Aid must have improved discrimination of timbre.

The low reliability and the lack of independence of these measures means that interpretation of the relationship of these measures to measures of performance must be provisional and have little practical use. The measure of auditory acuity was not significantly related to any of the measures of discrimination. It is, therefore, an independent measure.

Relationship of Measures of Audition to Measures of Performance with the Aid

Correlations of measures of audition with measures of performance with the Aid are presented in table 44. There was little association with measures from the training period. None of the coefficients has a probability of less than .01.

Auditory acuity was related ($p < .01$) to experimental performance only when the signal received by the Aid was very weak and the volume control of the Aid may not have allowed appropriate compensation. Measures of auditory discrimination were, however, related to measures of performance in the experimental sessions, particularly the discrimination sessions. All measures of auditory discrimination obtained before experimentation were negatively correlated (mainly $.05 < p < .01$) with size discrimination after constancy and with the variance of response. But pitch discrimination alone was related to distance discrimination ($p < .01$). Measures of auditory discrimination obtained after the experiment had different relations with these measures. Distance discrimination after constancy was still related to pitch discrimination alone and the variance was associated with texture and loudness discrimination. After constancy it was related not only to pitch discrimination but also to loudness and time discrimination.

Auditory discrimination was not related to the breakdown of constancy but the measures of pitch and time discrimination obtained before the experiment were related to measures of uncertainty of size and distance constancy respectively, when the objects differ on two variables. Cues relative to the nonjudged variable were related to uncertainty. The final measure of pitch discrimination was correlated with measures of uncertainty of distance constancy when the objects differ in texture, i.e., when the measures of uncertainty were not related to measures of the breakdown of constancy.

Measures of size judgements were negatively associated with the auditory measures throughout (with the exception of the relationship of timbre discrimination to the variance of the discrimination measures) while distance judgements were positively related. This suggests that while distance discrimination is based on one cue, size judgements are not only dependent on many cues, but also have an unusual relationship to the skill in judging these cues.

Measures of discrimination were also related to the subjects' ratings of ease of judgement. Pitch discrimination before experimentation was inversely related to ratings of ease of size judgements. Loudness discrimination after experimentation was inversely related to the rating of ease of distance judgements. Ratings of greater ease of judgement were given by subjects who were less able to discriminate the relevant variable. Thus the subjects' ratings of ease of judgements tended to be a function of the difficulty of discrimination of the nonjudged variables.

MEASURES OF PERSONALITY

The Eysenck Personality Inventory gives raw scores on two variables which are claimed to be orthogonal and described as extroversion (with its polar opposite

TABLE 45

Measures on the Eysenck Personality Inventory

Scale	Neuroticism	Extroversion	Lie
Experimental Subjects			
Mean	9.917	13.750	.833
s.d.	4.395	4.288	1.013
Norms for Students			
Mean	11.037	13.438	
s.d.	4.821	4.196	

TABLE 46

Intercorrelations of Measures on the E.P.I.

Scale	Neuroticism	Extroversion	Lie
Extroversion	.40	-	
Lie	.13	.14	-

TABLE 47

Correlation of Measures from the Eysenck Personality Inventory with Measures of Performance with the Aid

Measures of performance with the Aid				Personality Scale: Neuroticism	Extroversion	Lie	
Training Sessions	Sixth session	Size Judgements		.33	-.48	-.28	df = 14
		Distance Judgements		.03	.01	.16	
		Texture Judgements		.10	-.42	-.42	
	Seventh session	Size Judgements		.21	-.25	-.08	
		Distance Judgements		-.02	-.22	.02	
		Texture Judgements		-.01	-.22	-.25	
Discrimination Sessions	Size Judgements	j.n.d.	before constancy	-.05	-.05	.00	df = 66
			after constancy	.00	.05	-.15	
		Variance of complete data	before constancy	.16	-.16	.21*	df = 132
			after constancy	.11	.10	-.01	
		Variance of emended data	before constancy	.10	-.03	.10	
			after constancy	.11	-.05	.09	
		Response bias	before constancy	.23*	-.17	.01	
			after constancy	.12	.06	.02	
	Distance Judgements	j.n.d.	before constancy	.14	-.20	.00	df = 66
			after constancy	.25*	-.18	.14	
		Variance of complete data	before constancy	.03	-.09	.23*	df = 132
			after constancy	-.05	-.04	.06	
		Variance of emended data	before constancy	-.01	-.06	.22	
			after constancy	-.02	-.10	-.01	
		Response bias	before constancy	.19*	-.09	.01	
			after constancy	-.05	-.04	-.02	
Constancy Sessions	Size Judgements	Breakdown of Constancy	3h	.00	-.02	-.05	df = 22
			7h	.20	.05	.00	
			5c	-.25	-.08	-.06	
			7c	-.19	.00	-.26	
			3c	.16	-.24	-.06	
		Area of Uncertainty	3h	-.06	-.14	.20	
			7h	.34	-.23	-.18	
			5c	-.33	-.20	.20	
			7c	-.39	-.56**	-.24	
			3c	.23	-.42*	-.02	
	Distance Judgements	Breakdown of Constancy	4½h	.17	-.30	.13	
			8h	-.22	.21	.02	
			9c	-.20	.20	.24	
			8c	-.14	.07	.12	
			4½c	-.32	-.01	.25	
		Area of Uncertainty	4½h	.18	-.24	.01	
			8h	.13	-.29	-.04	
			9c	.01	-.10	.10	
			8c	-.05	-.30	-.01	
			4½c	-.59**	.09	.08	df = 22
Ease of Judgement Ratings	Size			.07	.25	-.38	df = 14
	Distance			-.45*	-.02	.40	
	Texture			-.30	.14	-.03	

* .05 < p < .01

** p < .01

introversion) and neuroticism (or stability). It also includes a lie scale which has no validation but was adapted from similar scales in the M.M.P.I. believed to measure social desirability (Hathaway and McKinley 1951). The mean and standard deviations of the measures on these scales obtained from the 24 experimental subjects are presented in table 45 together with the norms for students taken from the 1964 manual (Eysenck and Eysenck 1964). No norms are available for the lie scale. The results differed little from the norms with only a slightly lower score in neuroticism.

Interrelations among the Measures

The intercorrelations between the measures on this test are presented in table 46. They are much higher than those claimed by Eysenck and indicate that the measured neuroticism and extroversion are less independent than desired. They are, however, still sufficiently independent to be useful.

Relationships to Other Measures

The measures on these scales were correlated with measures of performance with the Aid (table 47) to examine the influences, if any, of these personality variables on such performance. There was no relationship to measures

TABLE 48

Correlation of Measures from the Eysenck Personality Inventory and Measures of Audition

d.f. = 22

Personality Scales			Neuroticism	Extroversion	Lie
Discrimination Measures from the Seashore	Measures taken before experimentation	Pitch	.05	.23	-.43*
		Loudness	-.06	.36	-.09
		Time	.14	.42*	.16
	Measures taken after experimentation	Pitch	.06	.00	-.09
		Loudness	-.40	.42*	-.01
		Time	-.15	.47*	-.14
		Timbre	.31	.29	.26
Measures of Auditory Acuity			.15	.05	.16

* $.05 < p < .01$

from the training sessions or measures of the breakdown of constancy.

The only measure of discrimination to correlate significantly with a personality variable was the after constancy measure of distance discrimination which was directly related to neuroticism; the more neurotic subjects discriminated less finely. Measures of the variance of the complete data from the discrimination sessions were significantly associated with scores on the lie scale and measures of response bias in the same session to measures of neuroticism. Measures of uncertainty associated with size constancy judgements were negatively correlated with measures of extroversion. The equivalent measure for distance constancy judgements, when the size and texture of the objects supplement each other, was negatively correlated with neuroticism. The greater the uncertainty the less the extroversion and neuroticism respectively.

The only rating of ease of judgement which was significantly related to personality variables was ease of distance judgements which was related to measures of neuroticism. Less neurotic subjects rated distance as more difficult to make.

The relationship of the measures of personality to other measures of individual differences are shown in table 48. The loudness and time subtests of the Seashore were directly related to measures of extroversion. The preliminary measure of pitch discrimination was inversely related to scores on the lie scale. The measure of auditory acuity was not related to personality attributes. Most of these relationships are significant between the .05 and .01 levels and thus should be interpreted cautiously.

Summary

The main findings were:

1) Differential training, or in fact any training with the Aid at all, had little effect on performance of psychophysical tasks. Training without movement led to more accurate judgements when the objects differ in more than one way in those situations where there are no background cues.

2) Measures of discrimination obtained by the method of limits, continuing through equality, were contaminated by a response strategy. The data was emended in an attempt to overcome this strategy.

3) The relationship of discrimination and stimulus magnitude did not depart significantly from linearity for either size or distance. Distance was discriminated more precisely than size and departed less

from the traditional Weber fraction.

4) Changes in distance and texture alters both perceived equality and the confidence of size judgements. Changes in texture alter both perceived equality and confidence of distance judgements, but change in size alters the confidence of distance judgements alone. Some constancy was demonstrated in all situations.

5) The additions of background cues had no significant effect on perceived equality, but decreased the confidence of size judgements in subjects who were not allowed to move during training.

6) Distance is rated the easiest judgement to make and size the most difficult.

7) Subjects claim that pitch is the basis of distance judgements, and timbre is the basis for texture judgements. Loudness and scanning width are both considered important for size judgements with disagreement as to their relative weightings.

8) Auditory discrimination improves after experience with the Aid. Pitch discrimination is related to distance discrimination. Auditory acuity has little relationship to performance with the Aid.

9) Personality measures are, to some degree, related to response bias, variability and constancy measures.

CHAPTER 4

DISCUSSION OF RESULTS

The aims and hypothesis presented at the end of chapter one will be discussed in order.

1. Evaluation of the Kay Ultra Aid

The research in this area is concerned mainly with general aims and not specific hypotheses.

a) To examine the influence of a short period of training, and of movement within this period, on later performance with the Aid.

Neither the experience of a training period, or of differential methods within this period, had much effect on later performance with the Aid. It is likely that the period allocated to training was far too short. This means that no definite conclusions can be presented as to the advantages of the different methods of training. However, subjects who were trained without movement within the environment gave slightly better performance when the stimuli varied in more than one way when there were no background cues. It would thus appear that, within the context of this experiment, the additional information provided during training by movement within the environment overloaded the subjects. This indicates that it might be better, when designing training schedules, to limit the amount of information available to the subject during the early stages of training.

b) To obtain quantitative measures of the following aspects of size and distance perception using the Aid:

i) Discrimination thresholds

ii) The extent to which estimates of size and distance remain constant when changes are made in the distance and/or texture, and size and/or texture, respectively, of the objects being judged.

Before these measures are discussed it must be emphasised that, due to the failure of the training period, we are examining the performance of as good as naive subjects. This highlights the very accurate perception displayed.

i) Estimates of discrimination thresholds were obtained at three magnitudes of size and distance for 24 subjects. The linear trends of the pooled measures were calculated giving a modified Weber Fraction for size and distance judgements using the Aid. The resulting equations were:-

Size - for radius of object $\Delta I = 0.025I + 0.554$

for area of object $\Delta I = 0.0007I + 0.554$

The linear trend accounted for 76% of the variance

Distance $\Delta I = 0.006I + 0.073$

The linear trend accounted for 96% of the variance

The large threshold constant in the size equations indicates that there is considerable 'perceptual noise' in the information leading to size. This is probably due to the width and distribution of the beam of ultrasonic energy emitted by the Aid. This implies that the trend obtained will probably be valid only over a small range of stimulus magnitudes, limited by the usefulness of the scanning action in estimating size. It also means that direct comparison of the Weber constant for size determined in this study with those, from other studies, which do not depart from the traditional Weber fraction, is not possible. To enable a rough comparison, approximations of the traditional Weber fraction were calculated by averaging the three fractions for pooled data at each stimulus magnitude. The resulting fractions are: radius .167 and area .017. Using these measures as a basis for comparison we find that distance discrimination is more precise than size discrimination over this stimulus range. Size discrimination with the Aid is more precise than echolocation; Rice and Feinstein (1966) found that blind subjects could discriminate objects with an area ratio as low as 1.07/1. The author was unable to find a reported constant for visual perception of area; the best comparison is that with visual perception of length. Weber (1834) found that the fraction for visual perception of length was 1/100; the Weber fraction for the equivalent measure of size discrimination with the Aid was .08, indicating that size discrimination with the Aid is not as sensitive as with normal vision.

Distance discrimination by echolocation was examined by Kellogg (1962) and the Weber fraction calculated from one stimulus magnitude was 1/4 inch; much larger than that found in this study. Kellogg also reports figures for visual perception, taken from Howard (1919), of 1/2 for monocular vision and 1/40 for binocular vision. Thus distance discrimination with the Aid seems to be more precise than with vision or echolocation.

In summary; both size and distance discrimination with the Aid are more precise than with echolocation, the only technique available to the non-aided blind individual, and distance discrimination is also more precise than with visual perception.

ii) The findings from this section can only be expressed in general terms because there is no satisfactory equation and it is almost impossible to quantify the texture differences, of the stimuli, at this time.

Perceived equality of size and the associated areas of uncertainty both change significantly with changes in the distance or texture of the object. Distance judgements of perceived equality are significantly influenced by the texture but not by the size of the stimuli. The measures of uncertainty associated with distance judgements are influenced significantly by both size and distance. The changes throughout are in the direction of a projective match and the mean of the size judgements is nearly as close to projective as objective equality. This is not true for distance judgements which depart little from objective equality. Constancy was not increased by the addition of extra background information indicating that the failure of the subjects to give objective responses was not due to the restricted context.

Training must aim to correct these influences as such constancy is necessary if the blind person is to manipulate the environment on the basis of the information obtained from the Aid. Unless such training produces considerable improvement in the capacity to judge size under such conditions the Aid cannot be said to provide satisfactory size perception in the limited range explored in this experiment.

c) To find how subjects interpret the skills involved in making size, distance and texture judgements with the Aid.

Almost every subject ranked distance as the easiest and size as the most difficult judgement to make. Pitch was given as the most important cue for distance judgements by almost all subjects, but scanning width and loudness are both reported by most subjects as cues to size judgements with little agreement as to their relative importance. Timbre was consistently reported as the most important cue to texture. These reported cues are consistent with the physical changes in the signal.

If the subjects' claims are accurate, distance and texture judgements are based on one clear cut cue, but size cues are based on at least two different cues with little agreement as to which is most important. This lack of one clear cut cue may explain why size judgements are considered to be the most difficult to make and are least stable.

d) To determine the relationship of measures of auditory acuity and discrimination to measures of performance with the Aid.

As the interpretation of the auditory signals from the Aid is the sole basis of perception with it one would expect that measures of pitch, loudness, time and timbre would be related to skill in judging those dimensions which are dependent on them. In contrast auditory acuity will probably not be related to performance with the Aid as, within normal limits, the control of the volume of the signal is determined by the user. In harmony with the latter prediction auditory acuity was related to performance with $p < .01$ only when the signal was at its softest and the range of the volume control may not have been sufficient.

Auditory discrimination, as measured by the Seashore Measures of Musical talents, improved slightly after experience with the Aid and the measures were related to measures of perceptual discrimination with it. The relationship of performance with measures of auditory discrimination obtained before experimentation may be used to predict the performance of potential users of the Aid. The low reliability of measures other than pitch reduces their usefulness.

Distance discrimination and the area of uncertainty of distance constancy judgements, when this measure is not related to the breakdown of constancy, were related to pitch discrimination. Size discrimination tends to be inversely related to pitch, loudness and time discrimination. Other measures of uncertainty in the constancy sessions are only weakly related ($.05 < p < .01$) to measures of auditory discrimination. These measures of uncertainty, together with the subjects' ease of judgement ratings, the variance of discrimination responses, and the distance judgements in the last training session were inversely related to the dimensions of the signal on which the nonjudged variable is based. This suggests that ease of judgement in a more complex situation is determined, in part, by the difficulty of assessing the variable not being judged.

Texture was judged only during the training sessions and the measures from the last training session are related to the initial measures of pitch discrimination, the final measure of time discrimination and the only measure of timbre discrimination. There is no way of determining what the relationship with texture discrimination would have been as there is a different pattern of relationships of size and distance judgements in training and discrimination sessions to auditory discrimination.

Riley, Weil, and Cohen (1966) also found that pitch descrimination, as measured by the 'Seashore' was related to performance with the Aid. As these authors used a completely different task, there can be little doubt that this measure is indeed related to such performance and that it may profitably be used to guide selection of potential users of the Aid. The relationship is not, however, very great - it accounts for less than half of the variance - and so not much weight can be placed on it.

e) To examine the relationship of personality variables, measured by the Eysenck Personality Inventory, to performance with the Aid.

Previous studies with the Aid and similar experimental designs suggest that there will be some relationship between measures of personality and measures from the experiment. Riley, Weil, and Cohen (1966) found that a measure of 'defensive inflexibility', a combination of measures of social desirability, flexibility, and intolerance of ambiguity, was related to performance with the Aid. The more flexible subjects performed better. Wilson (1965) found that the extroversion and neuroticism scales in the M.P.I. were related to judgements influenced by intersensory interaction and Mitchell (1966) found that the

Lie scale from the Eysenck Personality Inventory was related to the variance of judgements. This was thought to be an attempt by the subjects to satisfy their interpretation of the experimenter's desires.

Riley et.al., examined performance during training and suggested that the role of the personality variables lay in the lack of adaptation displayed by subjects high in 'defensive inflexibility'. The lack of any similar relationship between performance at the end of training, in this experiment, and the personality variables may be due to the almost negligible improvement shown in this period. However, little improvement occured in the Riley et.al. experiments either and the difference may be due to the different measures used or to an incorrect interpretation of the role of the personality variables; these variables may be related to the task rather than to ability to use the Aid. This claim is supported by Riley et.al.'s discovery that performance on similar tasks using the subject's normal aid was also related to personality variables, but performance in outdoor tests using the Kay Aid was not.

The relationship between perceived equality and personality variables, suggested by Wilson's finding with research into intersensory interaction, did not reach significance. However, the more sensitive measures of confidence associated with such judgements tended to be associated with extroversion (size judgements) and neuroticism (distance judgements), in harmony with the expectation; the less neurotic and more introverted subjects showing the least confidence.

Mitchell's discovery that the variance of measures obtained from the method of limits was associated with measures on the lie scale was supported by this experiment. Mitchell suggests that this is due to a response bias based on the subject's perception of the experimenter's desires. This explanation could be applied to our results, the relationship between neuroticism and, part of this variance, the measures of response bias obtained by differencing the upper and lower thresholds, could be due to similar factors.

In summary; personality variables, as measured by the Eysenck Personality Inventory, are related to factors dependent on the experimental situation and not to general performance with the Aid.

Summary of the Evaluation of the Aid

A short period of training had little influence on performance in the psychophysical tasks. This highlights the accuracy of size and distance perception displayed. Distance discrimination follows the traditional Weber's Law and is more precise than visual perception and echolocation. Size discrimination is linearly related to stimulus magnitude but has a large threshold constant, probably due to the nature of the ultrasonic beam emitted by the Aid, and thus departs from the traditional Weber's Law. This trend is possibly limited to the part of the stimulus range in which scanning width can be used and thus any direct comparison with other measures of size discrimination is impossible. There is, however, some indication that size discrimination with the Aid is worse than discrimination with visual perception and better than with echolocation.

Perceived equality of distance is influenced by differences in texture but not size while perception of size is influenced by differences in both distance and texture; size judgements also depart more from equality. Distance judgements are thus more stable than size judgements. Improvement in the stability of both judgements is needed if the information from the Aid is to be used for manipulating the environment. Training must aim to correct this perturbation of perception and unless considerably more skill can be induced by training, the

Aid cannot be said to provide satisfactory size perception. Such a skill may not be essential for navigation but would undoubtably aid it.

These results suggest that while perception in highly controlled and restricted contexts by naive subjects is very good, there is need for the development of skills which enable accurate perception in the more complex situations. The only improvement in performance due to training was found in the more complex situation when the stimulus could change in more ways than one. The subjects experiencing no movement within the environment during training, and thus receiving less information, making the more accurate judgements; the skill breaks down with the addition of extra unfamiliar background information. This improvement suggests that the necessary skills for accurate perception in such situations may be developed after a long training period in which the amount of information is restricted at the early stages and which gives specific training in the unrestricted environment later. Research should be conducted containing such an intensive programme and similar measures obtained. Until this is done the Aid cannot be satisfactorily evaluated.

Distance judgements are ranked by subjects as the easiest and are associated with one clear cut dimension of the signal (pitch) while size judgements are ranked as the most difficult and associated with two aspects of the signal (loudness and scanning width) with little agreement as to their relative importance. These claims of the subjects are supported by examination of the relationship of measures of auditory discrimination and performance with the Aid. These factors may be responsible for the differences between the accuracy of the two types of judgement.

Pitch discrimination as measured by the Seashore Measures of Musical Talents gives partial prediction of skill in distance discrimination with the Aid and may be useful in the selection of potential owners. Personality measures from the Eysenck Personality Inventory are chiefly related to variance and response bias in the psychophysical techniques used or to measures in the constancy situation which are probably also due to the experimental situation and not the Aid. This means that such personality measures will be of little use in predicting general performance with the Aid.

2. The Use of the New Perceptual System Provided by the Kay Ultra Aid for the Blind to Test Hypotheses Stemming from Theoretical Claims About Perception.

a) Movement within the environment in addition to judgements about the same, during training, will provide extra information about the relationships between the output of the Aid and the environment and hence lead to better performance with the Aid (if maximum information has not already been provided by the verbal feedback without movement).

The brief training period used in this experiment produced little or no change in the subjects' ability to make judgements based on the Aid and hence little conclusion can be reached as to the effects of differential training. Significant training effects were, however, found for distance judgements in the seventh training period when stimuli could change in more than one way, (the training group having no movement showed less error), and in interaction with background cues on the area of uncertainty associated with size constancy judgements. The same training group had the smallest area of uncertainty when no background cues were present and the greatest area of uncertainty when such cues were introduced. The latter results should be regarded with caution as there is evidence that measures of uncertainty for size constancy are contaminated. It would thus appear that movement during training hindered rather than aided learning with the Aid. This result can be interpreted within an informational interpretation of the role of movement during training as the extra information from movement could have overloaded the subjects with information and led to confusion.

The discovery that the significant effects of differential training occured mainly in those situations in which some constancy was demanded brings us to the second hypothesis.

b) Movement during training will provide different information concerning the invariants of the output from the Aid and hence lead to greater constancy.

The results discussed above are contrary to this hypothesis and suggest that the role of movement in the development of constancy, as in the development of all perceptual skills, is one of the provision of specific information rather than efferent -afferent interaction as suggested by Gyr, Brown, Willey and Zivian (1966). In this experiment the information provided by presenting the subject with many combinations of size, distance and texture of objects leads to greater development of constancy than the extra information provided by movement which overloads and hence confuses the subjects. The learning is specific to the training situation, however, and extra information can destroy it. Training with movement may thus still be needed for the final development of constancy during movement.

c) Background cues will provide additional information about the relationships within the stimulus context and thus lead to less uncertainty and greater constancy unless sufficient information is already available. This effect will be greatest for subjects at a low level of perceptual development as it is then that the additional information is needed more.

The only significant effect of the background information is in interaction with training on the uncertainty of size judgements, as mentioned above. It had no effect on perceived equality or on the area of uncertainty for distance judgements. Background cues thus decrease the precision of size constancy judgements from subjects who experienced no movement during training, by destroying the additional constancy developed by this group, leading to the greatest uncertainty displayed. This presumably stems from the destruction of the cues on which the judgements were based. This suggests that unfamiliar background information can destroy constancy established in a more restricted situation; additional information is useful only when the subject has learned to use it.

As all groups were at a low level of development with this perceptual skill, the latter part of the hypothesis cannot be evaluated.

d) Constancy is related to the ease and confidence with which judgements are made. The relationship between the confidence of the constancy judgements and their departure from constancy is bipolar, with a more rapid decrease in confidence being associated with the departure from projective equality judgements.

The similarity of the analyses of perceived equality and of areas of uncertainty associated with them, the only difference being explicable by the greater sensitivity of the analyses of uncertainty, suggests that the above claim is true. When we turn to the intercorrelations among these measures, however, we find that the evidence is not so clear. The wide range of responses obtained in the size constancy sessions and the limitation of the available stimulus range means that the relationship between the perceived equality and uncertainty of size constancy judgements cannot be properly examined. These restrictions do not hold for measures of distance constancy which, in harmony with the hypothesis, are directly associated when the objects differ in size alone or when size and texture differences are in opposition. The lack of relationship of the other measures can be accounted for by hypothesising a negatively accelerated increase in uncertainty so that individual differences quickly swamp the influence of the departure from objectivity, when the judgements are relatively stable. The association of these unrelated measures of uncertainty alone with measures of pitch discrimination supports this hypothesis.

Measures of ease and confidence of size judgements external to the constancy sessions, other than subjective ratings, are related to measures within them but the equivalent measures for distance judgements are not. The greater variance of size judgements may be partly responsible for this.

Operational measures of the ease of judgement within and without the constancy situation are thus related to the failure of constancy. Size judgements being associated with measures external to the constancy sessions and distance judgements to measures within them.

Subjective ranking of the variables for ease of judgement support the hypothesis as distance judgements are ranked as the easiest judgements and depart less from constancy. However, when the subjects' rankings of overall ease of judgement are correlated with constancy we find little relationship; the relationships that do reach significance are those with the non judged variable. There is, however, evidence that such rating is determined more by the difficulty of the non judged variable than the ease of judged variable, a contrast effect, so this evidence does not weaken the hypothesis.

e) Judgements which are based on one dimension of the output of the Aid, which is relatively independent of other aspects of the stimulus context, will depart less from constancy than those judgements which are based on more than one dimension and are not independent of other aspects of the stimulus context.

Before this hypothesis is discussed there must be an examination of the basis of size and distance judgements with the Aid and the influences of changes in the stimulus context on the relevant dimensions of the output from the Aid. Such an examination must be based on information from:-

i) The physical description of the signal

ii) Patterns of error in the training session

iii) Subject report

iv) The relationship of measures of auditory discrimination and performance with the Aid.

i) The Aid was so constructed that the pitch of its signal is linearly related to distance and is little influenced by changes in the stimulus situation. As bigger objects reflect more of the signal and take longer to scan, the size of the object is related to both scanning width and loudness. Texture judgements are related to loudness and timbre, because a rough surface scatters the sound. Size judgements are thus dependent on incidental attributes of the signal which change considerably with change in the stimulus context. Changes in both texture and distance alter the cues to size, but changes in texture alone, influence the cues to distance.

ii) Patterns of error in the training sessions demonstrated that the extreme stimuli are easily recognised and act as anchors when distance is judged but not when size is judged and that texture judgements are more dependent on changes in timbre than changes in loudness.

f) Those stimulus changes, which alter the output of the Aid in such a way that the dimensions on which judgements of another attribute are normally based are changed, will influence judgements of that attribute more than changes which alter only those dimensions of the output which are not normally involved in such a judgement.

The texture differences of the standard and variable in the constancy sessions cannot be claimed to be equal to the differences in size and distance of the same, and so discussion of this hypothesis must be dependent on the validity of the assumption that the obtained differences are not solely due to this inequality.

If this assumption is valid, the hypothesis is supported. Size judgements are influenced greatly by changes in both texture and distance. Both these changes alter the loudness and scanning width of the signal, the dimensions on which size judgements are based. Changes in texture have a significant influence on the subjective equality of distance but size differences do not. Texture alters the timbre of the note and thus increases the range of frequencies in the note upsetting perception of pitch while the size of the note alters only

iii) Subjects consistently report that distance judgements are the easiest to make and are primarily based on pitch differences. Texture judgements are reported next easiest to make and to be dependent on timbre differences. But although subjects agree in rating size judgements as the most difficult and in claiming that loudness and scanning width are important cues, they cannot agree which is the most important.

iv) Distance discrimination is consistently related to pitch discrimination but size judgements are not consistently related to one such variable.

The above evidence all indicates that distance judgements are based on pitch, a cue which alters little with changes in other variables, but size judgements are based on at least two dimensions of the signal (scanning width and loudness) which are greatly influenced by changes in the total stimulus situation and are more dependent on learning.

The hypothesis is thus supported as size judgements depart from constancy much more than do the distance judgements. Some size judgements approximate projective equality, and distance judgements differ very little from objective equality.

the loudness and scanning width of the signal; two irrelevant dimensions.

This supporting evidence is conditional only and cannot be more fully examined with the Aid until the differences of size, distance and texture can be measured in equally discriminable intervals.

g) When two such variables are altered at once, the effect will be additive.

This hypothesis is supported by the lack of significant interactions of size or distance and texture in the analyses of the results from the constancy sessions except when the restriction of the stimulus range prevented the desired match.

Summary of Research Stemming from Theoretical Claims

This section is concerned with two interrelated aspects of perception; the role of movement in perceptual learning and the nature of the perceptual constancies.

The first three hypotheses are mainly concerned with the role of movement in perceptual learning and as little training effect was found few conclusions can be drawn. There is, however, some support for the claim that the role of movement during training is to provide extra information to the subject, and some indication that this extra information may inhibit rather than aid learning on occasions, probably because it means that the information processing capacity of the individual is exceeded, resulting in confusion.

Training had the most effect, in complex situations when judgements had to be based on the perception of invariants, on those subjects not experiencing movement. There is evidence that the role of movement in the development of constancies is still that of provision of information and not that of efferent -afferent interaction suggested by Gyr, Brown, Willey and Zivian (1966). The learning is specific to the training situation as the provision of new information can destroy the established pattern of responding. Thus movement may still be necessary for final stages of learning.

The remaining hypotheses are concerned with constancy and are derived from a theory of constancy, which claims that the judgements in a constancy session are dependent on two polar perceptual sets and that constancy is related to some types of intersensory interaction. The verification of the hypotheses obtained does not verify the theory but does lend support to it. Constancy is greater when judgements are made with more confidence, as predicted by generalization from intersensory interaction. The relation is negatively accelerated and individual differences quickly supplant the differences due to constancy when the judgements are reasonably stable. Examination of the equivalent decline in the confidence of judgements departing from projective equality was not possible. The amount of constancy is dependent on the independence and directness of the cues on which the judgements are based and changes in different attributes of the stimulus are additive, in harmony with predicted changes in the weighting of the perceptual sets developed by specific changes in the stimulus context.

CONCLUSION

This study explored some of the previously neglected aspects of the evaluation of the Kay Ultra Aid for the blind. It attempted to explore some of the psychophysics of size and distance perception using the Aid with the naive subject and after different training schedules; with and without movement in the environment. It also examined the relationship of individual differences in audition and personality to performance with the Aid. The Aid was also used to examine theoretical claims concerning the role of movement on perceptual learning and the nature of perceptual constancy.

The short training period had little influence on perception with the Aid in the restricted psychophysical situation; those subjects trained without movement performed slightly better when constancy was demanded. Size and distance discrimination is satisfactory even in these, as good as naive subjects, distance discrimination is finer with the Aid than with visual perception. However, both size and distance judgements are distorted by changes in surface texture, size judgements are affected the most and are also distorted by changes in distance. If this is not improved by training, the Aid cannot provide for satisfactory manipulation of the environment. There is some indication that a properly conducted training schedule, with limitation of the early information output leading up to training in complex situations may improve perception in such conditions, but this remains to be tested. Distance judgements are based on one clear cut dimension of the signal of the Aid, this is not true for size and this may account for the greater subjective ease and stability of distance judgements.

Measures of pitch discrimination are related to distance discrimination but personality variables as measured by the Eysenck Personality Inventory are related to the specific experimental tasks rather than to performance with the Aid.

There is some support for the claim that the role of movement in perceptual learning and development is dependent on the increase in, and nature of, the information available, with evidence that such movement may lead to an inhibition of performance because of an overload of information. There is also some indirect support for a theory of constancy which claims that constancy judgements are determined by two polar perceptual sets and that the phenomenon is related to some types of intersensory interaction. Ease of judgement is related to the stability of constancy and this is influenced by the nature of the cues on which the judgements are based and their stability with changes in the stimulus context.

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APPENDIX I

The Aid.

Plate 1. Photograph of the Aid.

The Aid was held the other way up in the experiment so the volume control would be readily accessible in the apparatus.

Diagram of the frequency modulation system of the Aid. From Kay (1964).

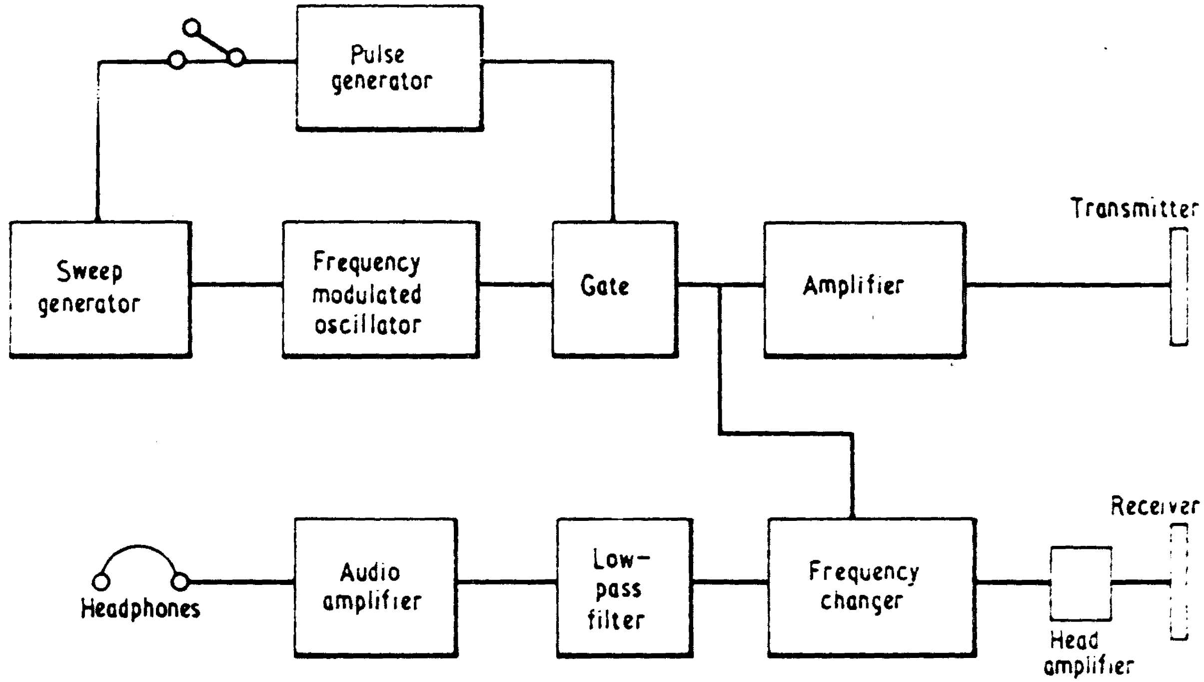


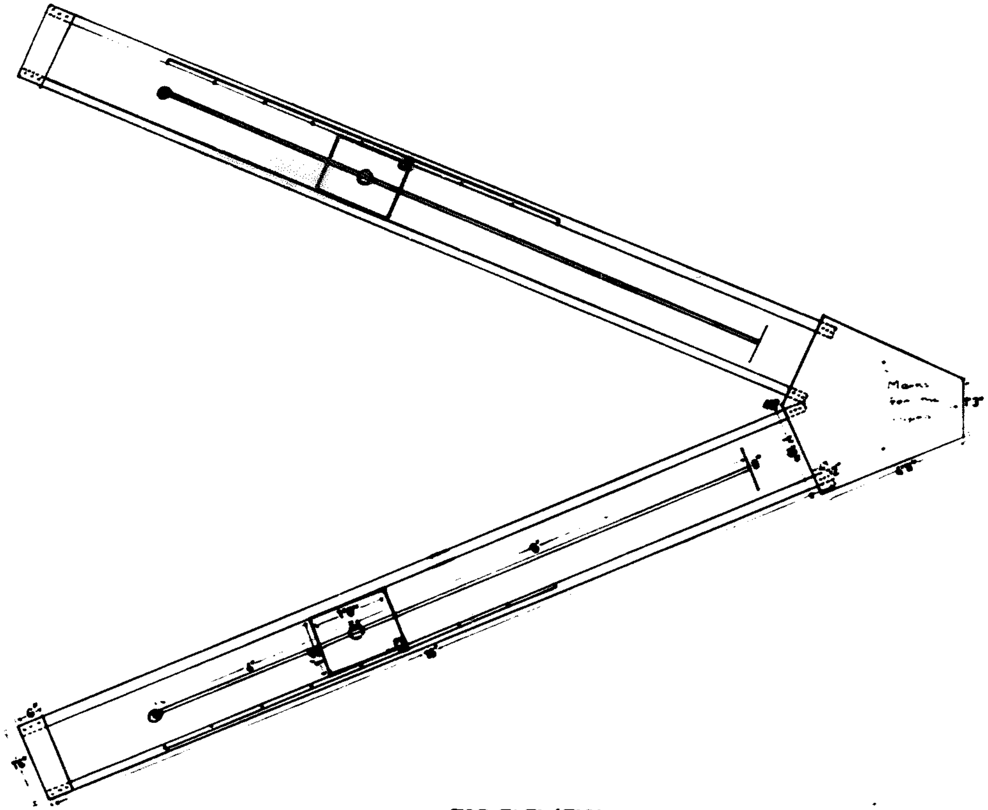
Fig. 2. Frequency-modulation system of aid

APPENDIX II

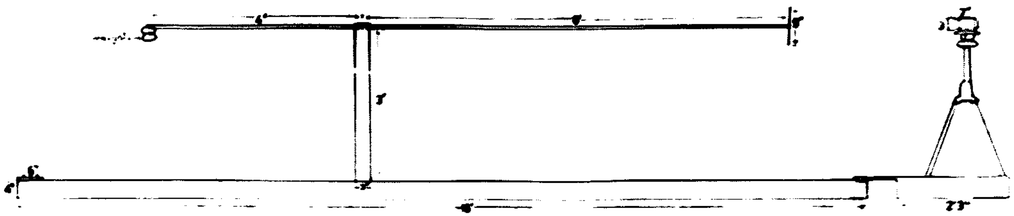
The Experimental Apparatus

Scale Diagram of the Apparatus

SCALE DIAGRAM OF THE APPARATUS



TOP ELEVATION

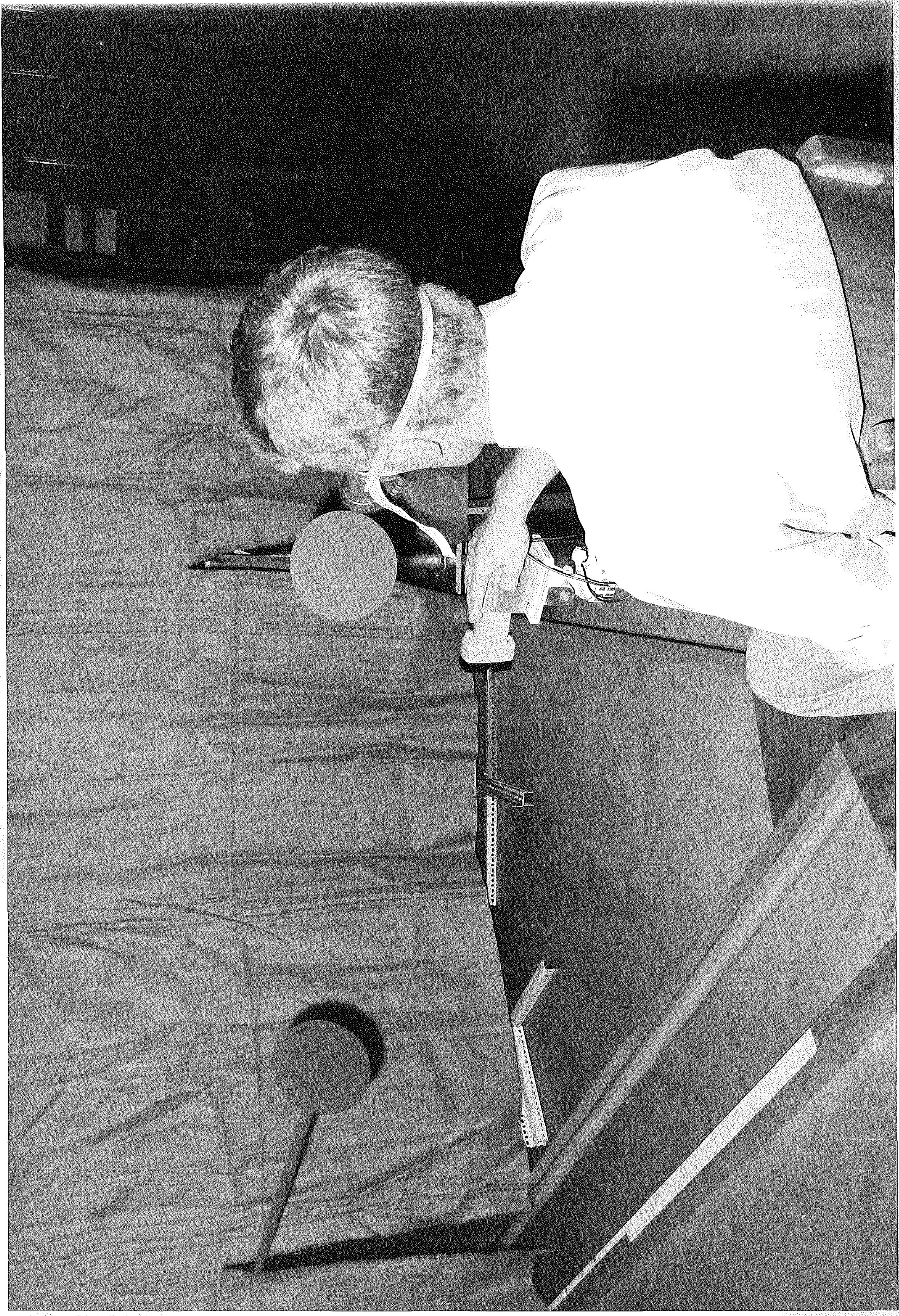


SIDE ELEVATION

Plate 2. Photograph of the Apparatus
in use.

Plate 3. Close up of the Subject and Aid

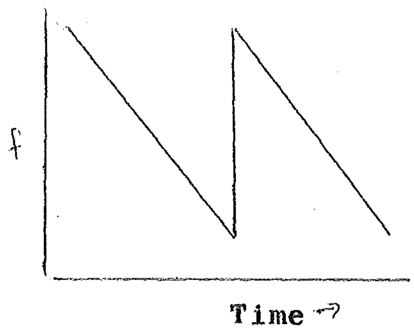
Plate 4. The Hessian Screen from the Constancy Sessions.



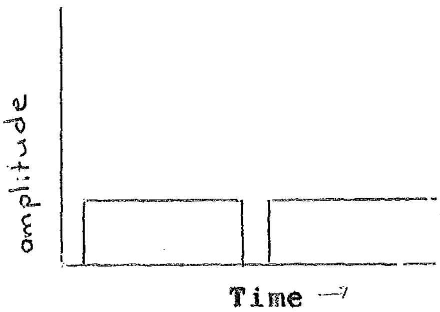
APPENDIX III

Introduction to the Aid

"This is the ultra-sonic aid that you will be using during this series of experiments. It consists of a transistorized transmitter-receiver in the shape of a torch which can easily be held in the hand. It transmits an ultrasonic beam of energy whose frequency varies with time although the amount of energy is constant. A graph of the change in frequency over time would look like this, (Diagram A), as the torch makes several sweeps from 90 kc to 45 kc, but a graph of intensity or amount of energy over time would be a straight line graph for the duration of each sweep, (Diagram B).



A



B

If this beam comes in contact with an object, some of it is reflected back to the torch. Any such reflected energy received by the torch differs in frequency from that leaving it, at that instant, by an amount proportional to the time taken for the energy to travel out and be reflected back, i.e., to the distance between the object and the torch. This has the effect, when translated into sounds we can hear, of producing differing signals in the ear piece, enabling the user to perceive obstacles which come within the range of the torch. The distance of the obstacles from the user can be determined by a difference in pitch - the higher the pitch the further away the object. The size and texture of the object can also be related to the type of signal; a larger object reflects more of the energy and thus gives rise to a louder note, a smooth surface reflects more of the energy at the same angle than does a rough or soft texture giving a purer and louder note.

For most of you the first few sessions will be used to teach you how to use the torch and later sessions will be used to test your ability to perceive size and distance when using the torch. However, the following people will be having no training and will start on the testing session as soon as the apparatus is ready which may not be for two weeks. I will contact you when I wish you to come.

To ensure that no visual cues are used you will be blindfolded during all the training and testing sessions before you enter this room. For this reason I will meet you in my room, at the end of this corridor, before each experimental session."

Before the first session using the aid each subject was introduced to its mechanisms in the author's study. This took the following form.

"First I will show you how to work the Aid. Hold it in your hand with this side up and fit the ear piece on your right ear, (unless you know you have a hearing defect in that ear). To turn the Aid on turn the knob on the top to the right; the same knob serves to control the volume, to make the volume louder turn it to the right and to make it softer turn it to the left. Throughout this experiment you will be left to adjust this to the level you find best (the middle range will probably be best). Try to keep it at approximately the same level.

On the bottom of the Aid is a small button which controls the range over which it is effective. If the button is left alone, the Aid has a range of from 0 to 10 feet; when it is pushed in, it has a range from 0 to 20 feet. In this series of experiments we will only be using the short range so take care not to press this button."

APPENDIX IV

THE QUESTIONNAIRE

Name:________________________ Date:__________________

N.B. Would those subjects who had no experience in judging texture (i.e., those having no training) please disregard those parts of Question 1 and 2 concerned with texture and omit question 5 completely.

1. Place a mark alongside the statement of which best describes the ease with which you made judgements of:

	Size	Distance	Texture
Extremely easy			
Very easy			
Easy			
Moderately easy			
Neither easy or difficult			
Moderately difficult			
Difficult			
Very difficult			
Extremely difficult			

2. Place the number one alongside the dimension you found easiest to judge, number two alongside the next hardest and number three alongside the hardest.

Distance _______

Size _______

Texture _______

3. Place a tick alongside the criteria you used when making distance judgements.

Pitch

Loudness

Scanning width

Timbre (purity of note)

Other (specify) ____________________

If you used more than one of the above criteria, rank those used in order of importance by placing number one alongside the criterion you found most useful, number two by the next, etc.

4. Place a tick alongside the criteria you used when making size judgements.

Pitch

Loudness

Scanning width

Timbre

Other (specify) ____________________

If you used more than one criterion, rank those used in order of importance as in question 2.

5. Place a tick alongside the criteria you used when making texture judgements.

Pitch

Loudness

Scanning width

Timbre

Other (specify) ____________________

If you used more than one, rank those used in order of importance.

APPENDIX V

Record Sheet for the Before Constancy Discrimination Sessions.

Nature of Judgement:________________

Subject:______________ Exp. session no.________ Date:______

Size of Standard:___________________

Distance of Standard:_______________

	VR			VL			VL			VR		
Order / Mv	a	d	a	d	a	d	a	d	a	d	a	d
x												

VR = Variable on the subject's right
VL = Variable on the subject's left
Mv = Magnitude of variable
a = ascending
d = descending

The record sheet for the after constancy sessions had one less series in each of the above sections. The alternating pattern of ascending and descending series was maintained.